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HUMAN PHYSIOLOGY

RITCHIE

1920 REVISION

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HUMAN PHYSIOLOGY

AN ELEMENTARY TEXT-BOOK WITH SPECIAL EMPHASIS ON HYGIENE AND SANITATION

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Know thyself! This precept of the ancients will hold good while the human race endures, and the first step in compliance with it is to learn something about the bodies that we inhabit. The author of *Human Physiology* believes that such knowledge ought to be given to the people by the schools which have been founded for their instruction; he is confident that modern knowledge is able to free our people from most of their illnesses. The purpose of this book is to present to upper grammar grade pupils the essentials of physiology, hygiene, and sanitation that every American citizen ought to know

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PREFACE

From a considerable experience with both very elementary and more advanced classes, the author has been led to certain conclusions in regard to the teaching of elementary physiology and hygiene. It is not proposed to enter here into a discussion of the correctness of these conclusions, but a brief statement of a few principles that seem fundamental may perhaps be allowable.

The chief object of teaching physiology in the public schools is to train the pupils to keep their bodies in health. The mere teaching of anatomy and physiology will not accomplish this, for the pupil cannot master the structure and workings of the body in a way that will enable him to frame the laws of health and apply them. Neither can the desired end be reached by teaching rules of health without an anatomical and physiological basis; for without such a basis, hygiene is an intangible and an elusive subject. The author has therefore concluded that a conservative middle course is wiser than either of the extremes of method mentioned above. An elementary text in physiology should be a *balanced* text, containing sufficient anatomy to make clear the broader outlines of the structure of the human body, enough physiology to make plain the great laws according to which the body lives, and a full discussion of how a violation of these laws may be avoided.

For the introduction of certain new matter, as, for example, the cell idea, the work of enzymes, and matter relating to germ diseases, there is little need for explanation. The groundwork of physiology and pathology has in recent years so shifted and extended itself, that the subject-matter of an elementary course must to a considerable extent be altered if it is to furnish a

proper basis for hygiene. The importance of teaching the known facts in regard to parasitic diseases and of training American citizens to apply measures for the prevention of these diseases, is now recognized, and the reason for the rather full treatment of communicable diseases will be understood.

One other point in connection with the teaching of physiology has constantly obtruded itself upon the writer. This is the age of science, but instead of teaching elementary science in our public schools, we are teaching unrelated fragments from different parts of the field of science. Physiology more than any other subject is the people's science, and it should be related to the nature study and the agriculture of the public school course. In a few places in this book an attempt has been made to lead the pupil into some of the byways that connect his physiology and nature study, and special emphasis has been given to certain facts that are necessary to an understanding not only of physiology, but of other subjects in the public school curriculum.

For counsel and very great assistance during the preparation of this text, the author must thank his friend, Dr. J. S. Caldwell of the Bureau of Plant Industry, United States Department of Agriculture. He is also under obligation to Mr. J. C. Freeman, who made the calculations for the table on pages 350–351; and for many suggestions and corrections he is indebted to the following persons: Dr. William H. Park, Dr. F. H. Pike, Dr. O. P. Jenkins, Dr. C. M. Hazen, Dr. E. G. Williams, Dr. S. O. Mast, Dr. J. A. C. Chandler, Professor C. W. Hetherington, Miss Virginia Jones, Edward Hughes, and W. I. Chapman.

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INTRODUCTORY

Did you ever get up in the morning and find that all the world seemed bright? And did you ever get up on another morning and find that all the world was dull? Do you remember how on the one morning you sang over your work and ran on your way to school? And how on the other morning you blundered and fretted over your work and did not care to play? On the one day you were so happy that every one was pleased to see you. On the other day you were not a pleasant companion for any one. On the one day the world seemed a beautiful place, and work was easy. On the other day all the world was dull, and every task was hard and disagreeable.

Why were you happy and joyous one morning and miserable and unhappy the next? Why did you cheerfully do your work one day and hate the same work the next day? Was it money, clothes, or education that made you happy? Was it a lack of them that made you unhappy? All these things are important, but there is something else much more important than all of them, — something that causes happiness to bubble up within you no matter what the world is like; something that keeps the heart beating strong with hope, and makes you laugh at hard work; something without which all the wealth of the world cannot make you happy, and with which any sound-minded person can lead a useful and a

successful life. *This something that can so change all the world for you is the health of your own body.*

It is not possible for every one to be always in perfect health. Sickness is bound to come to some of us, for there are many things about the human body that we still do not understand and there are certain ailments that as yet we have not learned to escape or cure. It is possible through the knowledge that we now have, however, to be set free from the greater part of the sickness that at present burdens us. In this book we shall, therefore, study the human body and how to keep it in health.

CHAPTER I

THE HUMAN BODY A COLONY OF CELLS

WHEN you view a brick house from a distance you do not see the bricks of which the house is built; but if you look at the house through a telescope or come close to it, you see clearly the bricks in the walls of the house. The house which from a distance appears to be one object is seen to be com-

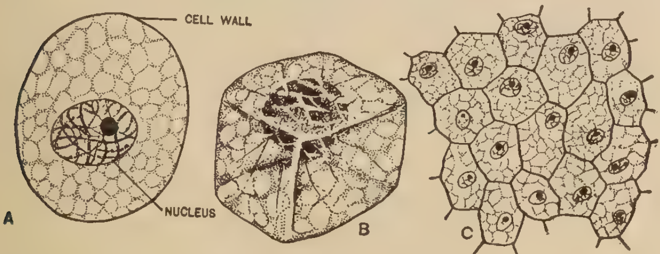


FIG. 1. Cells. *A* is a single cell as it appears under the microscope; *B* is a cell showing that it has length, breadth, and thickness; and *C* is a group of cells. A cell found alone usually has a somewhat spherical shape, as shown in *A*. When cells grow in groups they press against each other and usually have an irregular shape, as shown in *C*.

posed of a great number of smaller objects built together to form one whole.

The human body is composed of many small parts called *cells*. When we look at the body we cannot see the cells; but when a small portion of flesh or skin or other part of the body is examined under the microscope, the little parts which

make up the body can be distinctly seen. As the walls of the house are built of bricks, so the human body is built of cells.

The Cell. A cell is a small portion of a transparent, jelly-like material called *protoplasm*.[1] Usually a cell has a thin wall about it, so that it is like a little sac filled with a clear, half-liquid substance. In each cell is a *nucleus*, which is a denser portion of the protoplasm. Both the nucleus and the less dense material[2] around it take in food and grow; both of them are alive. Taken together they are the protoplasm, the living substance of the cell.

Living Things composed of Cells. As a heap of sand is composed of small grains, so are living things composed of very tiny cells.[3] Every blade of grass, every weed, every flower, and every tree is made of cells. Every animal, whether it be large or small, whether it live in the water, on the land, or in the air, is composed of cells. Dead materials, like earth, stones, water, and air, are not made of cells, but there is nothing living that is not composed of cells.

How Cells are formed. The ancient Egyptians thought that crocodiles and frogs came from the mud of the river Nile, and a great Grecian philosopher believed that insects sprang from the dew. A wise old scholar once told the people how mice could be created from wheat and stagnant water. Two hundred years ago, it was commonly believed that maggots came from meat and cheese, and that worms, insects, snails, and eels came out of decaying matter and

[1] In the back of the book the pupil will find a glossary that gives the pronunciations and meanings of many of the more difficult words.

[2] The lighter portion of the protoplasm is called *cytoplasm*.

[3] A few cells, for example, a frog's egg, are large enough to be seen with the naked eye. In general, however, cells are very small; so small that it would require twenty-five hundred cells from the human body to make a row an inch long.

mud. Fifty years ago, many physicians and other scientific men believed that disease germs and other little microbes were formed from unclean and decaying matter, and many persons still think that this is true.

We know now that all these ideas are incorrect. All living things, from the smallest germ to the greatest whale, are made of cells, and a cell can come, not from dead matter, but only from another living cell.

FIG. 2. Cell division. The nucleus of the cell divides and part goes to each end of the cell. A wall is formed across the cell, dividing it into two parts, each of which is a cell. All new cells are formed in this way.

The nucleus of a cell divides, and part of it goes to each end of the cell. Then a wall forms across the cell, and divides it into two parts. Each part is a new cell with its own nucleus, and each part grows as large as the parent cell. All new cells are formed in this way. "Every cell comes from a cell."

One-Celled and Many-Celled Animals. In a drop of stagnant water many hundreds of little animals may sometimes be found,—animals so small that you can see them only with a microscope. One of these little animals has only one cell in its body. The animal is a single cell that swims about alone and lives by itself. When this cell divides, the two new cells separate, and each one forms a new animal.

The bodies of all the larger animals (for example, the body of the chick in an egg) begin with a single cell, but when this cell divides, the new cells do not separate, like those of the one-celled animals. The cells remain together and keep on dividing and dividing until, in the body of a large animal, like a man, there are millions and millions of cells, — more than you could count in many years. The

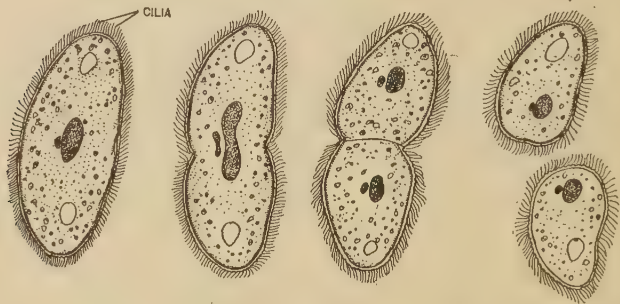


FIG. 3. A one-celled animal dividing. This cell swims about in the water by means of small hair-like *cilia* which beat the water. When it divides, the new cells separate instead of remaining together as they do in the many-celled animals.

difference between the little one-celled animals and the larger many-celled animals is therefore this: in one-celled animals, the cells separate after they divide and each cell lives alone. In the many-celled animals, the cells remain together after division, and live in a great colony.

Your body, therefore, is a great colony of cells, and each cell in it corresponds to an entire one-celled animal. You might almost think of yourself as made up of a great community of little animals, yet this idea would not be wholly correct. The cells of our bodies have learned to live together. They would die if separated, and it takes them all to make one complete animal.

Different Kinds of Cells do Different Kinds of Work. The single cell of a one-celled animal must do many different kinds of work to live. It has no hands to get food for it, no teeth to chew the food, and no stomach to digest it. It has no lungs to breathe in oxygen, and no kidneys to throw off its poisonous wastes. It lives all alone, with no other cells to help it, and it must do everything for itself. Each cell in the human body has the same needs as the little animal cell which lives alone. Each must have food, must get oxygen from the air, and must get rid of its poisonous wastes. Many of our cells are shut up in the center of the body, where they can get neither food nor oxygen for themselves, and their waste matter would poison both themselves and their neighbors if there were not some way of getting it entirely out of the body. Each cell cannot take care of itself, as does the little animal in the drop of water.

You can easily see how much it would be to the advantage of all the cells in the body for each one to give up trying to do everything for itself, and for all of them to unite and work for the good of the whole community. This they have done. They have divided the work, and each cell has taken for its own some special task. The cells of the stomach digest the food; the bone cells build up a strong framework to support the body; the muscle cells move the body; the kidney cells throw out wastes; the lung cells take in oxygen from the air; and the cells of the blood (red blood corpuscles) carry oxygen through all the body to the cells. Each cell is a skilled workman doing some particular work for the body as a whole, and not

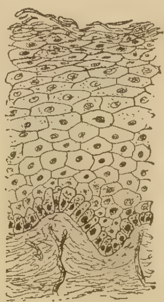
FIG. 4. Cells from a gland of the stomach. The function (work) of these cells is to digest the food.

Connective tissue. In its first stage connective tissue is a group of cells which build around themselves a mass of jelly-like material, as shown in *A*. This material hardens into the fibers that are seen between the cells in *B*. All through the body a framework of connective tissue runs, holding the cells, organs, and tissues in place.

A muscle cell from the stomach. The muscle cells have the work of moving the body.

Bone cells. These much-branched cells deposit around themselves bone material (*b*), thus building bones to support the body. The bone cells build a network of fibers like dense connective tissue and then fill the spaces between the fibers with hard mineral matter. *a* is a cavity from which the bone cell has been removed.

One of the nerve cells from the brain. These cells are associated with thought.



Cells of the outer layer of the skin. These cells form a protective covering for the body. The outer cells die and dry up until they are mere scales.

Fat cells. Food for the body is stored in these cells. Large quantities of fat collect in the cell, and crowd the protoplasm (*a* and *b*) to one side. A fat cell is little more than a bag of oil.

FIG. 5. Cells from the human body. Each kind of cell in the body has a particular work to do for the body as a whole.

an unskilled laborer trying to do all the many different kinds of work necessary to provide for its own wants.

The Cells Dependent on Each Other. You will now understand that the cells in the body must depend on each other for many things. If the stomach fails to digest the food, there will be a lack of food in all the cells. If the kidneys do not throw off the wastes, all the cells will be poisoned. If the lungs stop taking in oxygen, all the cells must die for lack of oxygen. If part of the cells fail in their work, all the cells must suffer, and death usually comes to the body because part of the cells have ceased to work.

The Body compared to a Community. The resemblance between the body and a community of people must now be very clear to you. In both the body and the community we have individuals, each leading his own life and yet making a part of a greater whole. In the community we have individuals of different occupations, — doctors, teachers, carpenters, blacksmiths, grocers, and milkmen. In the body we have, as we have seen, cells of different kinds, — muscle cells, bone cells, digestive cells, and many others. In both the body and the community the individual does not provide everything that he uses, but depends on others for many things. The carpenter builds houses for the milkman and the grocer, and these persons bring the carpenter his food. The stomach cells digest food for the cells of the lungs, and the lung cells take in oxygen for the stomach cells.

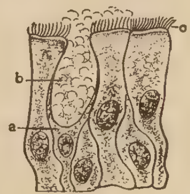


FIG. 7. Cells from the lining of the trachea. *a* is a cell that manufactures sticky mucus (*b*) in which dust and germs from the air are caught. The cilia (*c*) on the other cells beat upward and sweep the mucus, dust, and germs up out of the air passages and lungs.

Communities are prosperous and the body is healthy only

when the individuals do their work faithfully and well; for no person in a community lives to himself, and no cell in the body lives to itself, but each has a share in the life of all. New individuals from time to time are born into the community and other individuals die. New cells are constantly being formed in the body, and every day millions of cells in the body are destroyed. Communities increase in size when the number of births in them exceeds the number of deaths, and the body grows when the number of new cells formed in it is greater than is the number of the cells that die. Thus in many ways the body resembles a community of people where each individual is doing something for the good of all.

FIG. 7. Cells from the blood. *A* is a white corpuscle whose function is to kill disease germs; *B* is an edge view and *C* is a side view of the red corpuscles that carry oxygen through the body.

Tissues. If you have now in mind what has been said about cells and their work, you will have no difficulty in understanding what is meant by *tissues*. In a factory we usually find the workmen who do the same kind of work all collected in one part of the factory. So in the body we usually find grouped together the cells which do the same kind of work. The great group of nerve cells is in the brain. The muscle cells are collected in the muscles, and the kidney cells in the kidneys. Where cells of one kind are grouped, a tissue is formed, so we may say that *a tissue is a group of cells which do the same kind of work*. Muscle tissue is made of muscle cells, fatty tissue of fat cells, and nerve tissue of nerve cells. Each tissue is a group of cells which do some particular work for the body as a whole, and in return have many things done for them by the cells of other tissues.

Organs. *An organ is a part of the body that does a special work.* The kidney is an organ for throwing out wastes, the lungs are organs for taking in oxygen, the eye is an organ for seeing, and the stomach is an organ for storing and digesting food. Some organs, like the liver, the kidneys, and the heart, are chiefly of one kind of tissue. Other organs have in them many kinds of tissues. The hand is an example of an organ of this kind, bone, connective tissue, muscle, and skin all being united in it to form an organ for grasping.

Why you should understand the Cell. It is very important for you to understand the cell, *because a clear idea of the cell will give you a new way of thinking about all living things.* Having an understanding of it, you will not only think of an animal as a living thing, but you will also think of the millions of cells in its body, each filled with living protoplasm. When you see a plant cut down, or an insect, or a frog, or a bird killed, you will not only think of how the plant or animal dies, but you will think of how all the little cells in its body also die; and from thinking of the living objects about you in this new way, you will become interested in many things which you do not now notice, and will understand much that now seems strange to you. When you see a rose living for several days after it has been cut from the bush and placed in water, or when you see a branch of a plant living and growing when placed in the soil, you will know that when a part of a plant is cut off from the body of the plant, its cells need not always die. If you read that when a starfish, or certain kinds of worms, are cut into pieces, each piece grows into a complete animal, you will see that in these animals, as in plants, the cells are more independent than in the human body, and that a group of them is able to live without the rest of

the body. Also, when you learn to think of animals as groups of cells, you will not wonder that a frog's legs should twitch and jerk in the skillet; or that after the head has been cut off, a snake's tail can live and move, and a turtle can walk about. For you will understand that in these animals, as in the rose, part of the cells can live for a time without the others, and that the muscle cells are living and moving after the brain cells are dead. All these things and many others you can clear up for yourself, if you will think about the cell instead of about the body as a whole.

A second very important reason why you should understand the cell is *that you may intelligently care for your own bodies*. Each of the great multitude of cells in your body is following out its own little life, and each is industriously working for the good of the community in which it lives. We hope that you will understand that your cells must have proper food, oxygen, exercise, and rest, and that they must get rid of their waste matter. You should realize that any medicine you take can act on the body only by being carried by the blood through the body and entering the living protoplasm of the cells. If it helps the cells, it is beneficial to the body, and if it injures the cells, it injures the body. You should understand how reckless it is to take in among all these delicate cells patent medicines, headache remedies, alcohol, or tobacco, unless you are perfectly certain that these things will not harm the cells. For the cells of your body are the most important things in all the world to you. If they become diseased, you will fall sick; and if they fail in their work, your life must cease. When the bricks crumble, the house falls; and when the cells are dead, the body is dead, for the life is in the cell.

There is a third reason why you should understand the

cell, and that is *because in physiology we constantly study the work of the different kinds of cells.* If you did not understand the figures 1, 2, 3, and 4, you would get very little pleasure or profit from trying to solve problems in arithmetic; and if you do not understand what a cell is and how the body is made up of cells, you will think that physiology is a dull subject indeed, and it will never mean much to you. But understanding the cell, you can study the different parts of the body intelligently, and in all the world you will find nothing more wonderful or interesting than your own body.

Anatomy, Physiology, and Hygiene. *Anatomy is the study of the structure of the body,*—the study of the way all its organs are composed of tissues and its tissues made of cells. and of how all the organs and tissues are joined together to make one body. *Physiology is the study of the function of the different cells, tissues, and organs,*—the study of the work which all the different parts of the body do. *Hygiene is the study of how to keep the body in health.* These three subjects we must study in this book.

Summary. The human body, like all other living things, is composed of cells. Each cell is a little piece of protoplasm that takes in food and grows and is alive. Cells are formed only by the division of other cells, and living things can come only from other living things of the same kind. They cannot come from dead matter, although this has often been believed.

When a one-celled animal divides, the new cells separate. In many-celled animals the cells remain together after division, and the bodies of the larger animals are great colonies of cells. Each cell of the human body corresponds to an entire one-celled animal. Each cell in the body, like a one-

celled animal, must have food and oxygen and must get rid of its wastes.

It would not be possible for a cell in the body to supply all of its own wants, so each cell spends all its time in one kind of work, and depends on other cells for many things that are necessary to its life. It follows, therefore, that when part of the cells in the body fail in their work the whole body must die. The division of labor among the cells causes the body in a striking way to resemble a community where the people have different occupations and each one has many of his wants supplied by others.

As the workmen who do the same kind of work in a factory are often found together, so the cells that do the same kind of work in the body are found in groups. Such a group of cells — cells that do the same kind of work — is called a *tissue*. An *organ* is a part of the body that, like the hand or the eye, is fitted for some special work. It may be composed chiefly of one or of many kinds of tissues.

A clear idea of the cell is a very great help in understanding all living things, in caring for our own bodies, and in the study of physiology. Anatomy is the study of the structure of the body, Physiology is the study of the function of the different organs of the body, and Hygiene is the study of how to keep the body in health.

QUESTIONS

Of what is the human body composed? Describe or draw a cell. What kind of objects are composed of cells? How are new cells formed? Where do living things come from? Give some of the beliefs that have been held by different people in regard to the origin of animals and plants. Describe the process of cell division.

In a one-celled animal what do the cells do after division? What do the cells do after division in a many-celled animal? What in the human body corresponds to an entire one-celled animal? What are some of the needs of a cell?

Explain why a cell in the body could not provide for all its own wants. Name some of the different kinds of cells in the body and explain the function (work) of each. What happens to the body if part of the cells fail in their work? Give examples of cells that must do their work to keep the body alive. Mention some ways in which the body corresponds to a community of people.

What is a tissue? Name some of the body tissues. What is an organ? Name some organs of the body and give their functions.

Give three reasons why it is important to understand the cell.

What is Anatomy? Physiology? Hygiene?

If a cell and a peach were compared, what part of the cell would correspond to the seed of the peach? to the flesh of the peach? to the skin of the peach?

In an egg there is one living cell lying on the side of the yolk. What is necessary to make this cell grow and divide? Of what use are the yolk and white of the egg to the cell within the egg? Into what have the yolk and the white been changed by the time the egg hatches?

Does the cell in a duck's egg grow into a duck and the cell in a hen's egg into a chick because the food supply in the eggs is different, or because the living cells in the eggs are different? Are the cells of your body always composed of the same materials, no matter what kind of food you eat?

Can a branch be transferred from one tree to another and still live? Can a piece of tissue be transferred from one person to another? Ask a physician if cells from the body of an animal can be transplanted to the human body.

What happens in a wound when it heals? Ask a physician how the cells in a scar differ from the cells in other parts of the skin.

CHAPTER II

THE PLAN OF THE HUMAN BODY

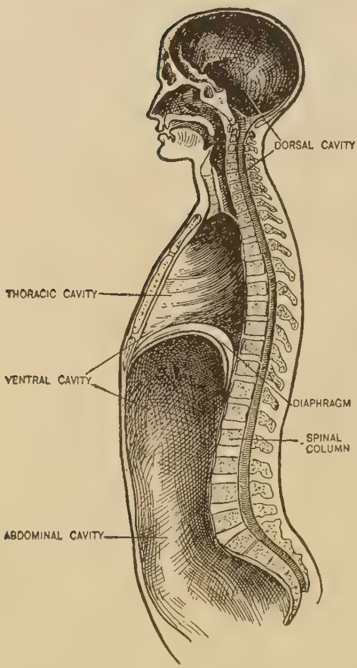


FIG. 8. The cavities of the body. The dorsal cavity is in the head and the spinal column. The ventral cavity is in the front of the trunk and is divided by the diaphragm into an upper and a lower part.

THE human body is composed of a head, a trunk, and two pairs of limbs. It is supported by a skeleton, the most important part of which is the *spinal column*, or backbone. In the head are eyes, ears, a nose, and a mouth. The body has in it two cavities, a *dorsal* or back cavity, and a *ventral* or front cavity. In these two cavities are found most of the organs of the body.

The Dorsal Cavity. In the head is a great cavity, and opening out of this cavity at the base is a long passageway that runs through the spinal column from top to bottom. The cavity in the head and the canal in the backbone, taken together, are the dorsal[1] cavity. In this cavity lie the great centers of the nervous system, the *brain* and the *spinal cord*.

[1] The name *dorsal* comes from *dor'sum*, the Latin word for *back*. In the lower animals it is easy to see that the cavity in the head and the canal in the spinal

The Ventral Cavity. The ventral cavity is a great hollow in the front part of the trunk. Stretched across it is a thin sheet of muscle, called the *diaphragm*, which divides it into an upper and a lower part. The upper part is the *chest* or *thoracic cavity*. It contains the heart and lungs and many of the great blood vessels. The lower part is the *abdominal cavity*. In the left side of this cavity, its outer end close up under the diaphragm, lies the stomach. On the right side of the body and partly covering the stomach is the liver. The intestine is very long and is coiled again and again in the abdominal cavity, filling most of it. Attached to the back walls of the cavity are the two kidneys, which take waste matter out of the body. At the left end of the stomach is a dark red organ called the *spleen*. Along the lower back part of the stomach is the *pancreas*, a very important digestive organ, whose work we must take up in another chapter.

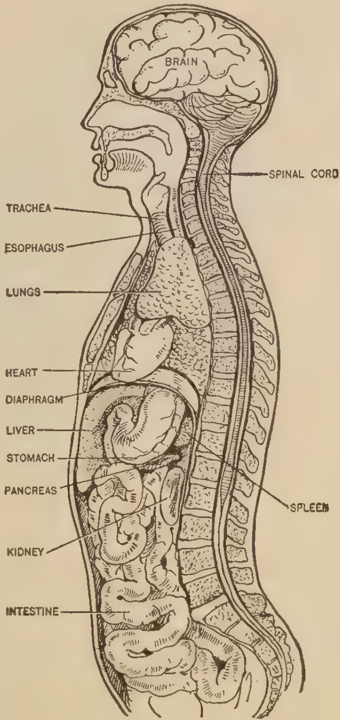


FIG. 9. Section of the body showing the positions of the organs in the cavities.

Man's Place in the Animal Kingdom. Man has a spinal

column are all part of one long cavity that runs along the back of the body and widens out at the head end to make room for the brain.

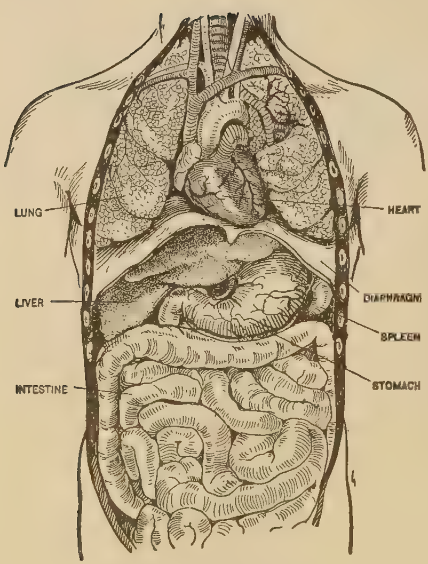


FIG. 10. The organs in the ventral cavity, seen from the front.

column, and therefore belongs among the *vertebrates*,[1] or backboned animals. He has hair, and when young lives on milk, and therefore he belongs among the *mammals*, the highest class of the vertebrates. The five classes of vertebrates are the fishes, amphibians, reptiles, birds, and mammals. By studying Figure 11, you can learn some of the animals that belong in each class, and which animals are closely related to man.

The Bodies of Vertebrates Similar. A fish, a frog, a lizard, a bird, and a cat do

[1] The vertebrates differ from worms, insects, and other lower animals in having backbones. The five classes of vertebrates have the following distinguishing characteristics:

Fishes live in the water and breathe by means of gills.

Amphibians have sticky skins, and both lungs and gills. Some salamanders have lungs and gills at the same time and can breathe either in the water or in the air. Other salamanders have gills at one time and lungs at another. Frogs and toads have gills in their early life and lungs in their later life.

Reptiles have scaly skins and breathe by means of lungs. Like the fishes and amphibians, reptiles are cold blooded.

Birds have wings and a body covering of feathers.

Mammals have the body partly or entirely covered with hair and feed their young with milk. The mammals and birds are warm blooded.

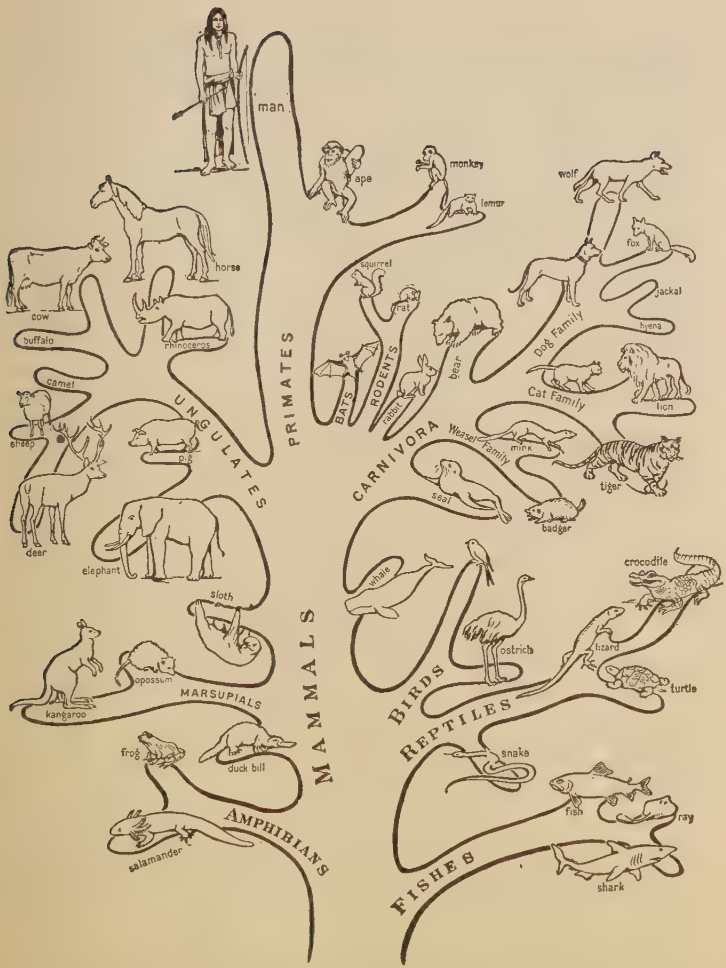


FIG. 11. The vertebrate animals. Man stands at the head of the mammals, the highest class of the vertebrates.

not seem much alike; and because man walks upright, the human body seems very different from the bodies of all these animals. Yet man and all other vertebrate animals are built on the same general plan.

Like man, all the vertebrate animals have a head and trunk, with eyes, ears, and a mouth in the head. All of them have a dorsal and a ventral cavity in the body, with in general the same organs in these cavities as are found in man. All have skeletons resembling the human skeleton, not only in the spinal column, but also in many other parts, as we shall see later. All of them have two pairs of limbs corresponding to the arms and the legs of man. In a fish, the limbs are the two pairs of fins found on the sides of the body. In the seal and the whale, they are paddles for swimming. In most other animals, they are the fore and hind legs, but in bats and birds the fore limbs are wings, and in man they are arms. Most snakes have lost their limbs, but in some of the great snakes the remains of little legs can be found, and in other reptiles the limbs are well developed.

How Man differs from Other Vertebrates. The brain of man is better developed than is the brain of any other animal, and in many ways the human body differs to a certain extent from the bodies of other vertebrates. But the great difference between man's body and the bodies of other animals is that man is built to walk erect. Instead of carrying the head in front of the body and walking on all four limbs in the position that a fish is in when it swims or a cat is in when it walks, the human body stands on the hind limbs, with the body erect and the head above the body. When the body stands upright the fore limbs do not touch the ground. Therefore, in man the fore limbs are not fitted for walking, but are arms and have hands for grasping.

Summary. The human body is composed of a head, a trunk, and two pairs of limbs. It has in it a dorsal and a ventral cavity. The dorsal cavity contains the brain and the spinal cord; the ventral cavity is divided by the diaphragm into the thoracic cavity and the abdominal cavity. The thoracic cavity contains the heart, the lungs, and many great blood vessels. The abdominal cavity contains the stomach, intestine, liver, spleen, pancreas, and kidneys.

Animals with backbones are called vertebrates. Vertebrates are divided into five classes, — fishes, amphibians, reptiles, birds, and mammals. Man has a backbone, and is a vertebrate. He has hair, and when young lives on milk; he is therefore a mammal.

The bodies of other vertebrates are built on the same plan as the human body. Every vertebrate has a head, trunk, eyes, ears, and a mouth. In the body are a dorsal cavity and a ventral cavity. It has a skeleton with a backbone, and has two pairs of limbs corresponding to our arms and legs.

Man's body differs from other vertebrate bodies chiefly in that it stands erect. The fore limbs do not touch the ground in walking, and are arms with hands.

QUESTIONS

Name the principal divisions of the human body. How is the body supported? What two cavities are in the body?

Where is the dorsal cavity? What does it contain? Into what two parts is the ventral cavity divided? What is the partition between these parts called? Name the organs in the thoracic cavity; in the abdominal cavity. Locate the stomach. Locate the liver.

Name the five classes of vertebrates. To which class does man belong? How does this class differ from other vertebrates?

Give four ways in which the bodies of all vertebrates are similar. Mention some different kinds of vertebrate limbs. How does man differ from other vertebrate animals?

What animals do you know that are not vertebrates? Can you name an animal that has no head? one with no mouth? one with no eyes? one with no ears? Name some animals that differ from vertebrates in the number of their limbs.

How does a fish differ from other vertebrates? What is the difference between a shark and a true fish? How does an amphibian differ from other vertebrates? a reptile? What are the four reptile groups? What do you know about the reptiles that lived in former ages of the world?

Which is the lowest mammal shown in Figure 11? In what way is this mammal like birds and reptiles, and different from the mammals of other groups? How do marsupials differ from other mammals? In what country is the sloth found? Name some mammals that live in the water. Do these mammals have lungs or gills? On what do the ungulates (hoofed animals) feed? On what do the carnivora feed? the primates?

Can you name some relative of the seal? Where do most of the weasel family live and what is obtained from this group of animals? Name some members of the cat family not shown in Figure 11; of the dog family. What small North American animal is closely related to the bears? Name some rodents (gnawers) that are larger than any of the rodents shown in Figure 11. Draw in a larger form the ungulate branch of the vertebrate tree, putting on it all the hoofed animals that you know. Do you know any families of mammals not shown in Figure 11?

CHAPTER III

THE RULER OF THE BODY

ALL parts of the body must be controlled and made to work together. Over them all a ruler must be set. Not only must the different organs be kept at work, but each must be made to do the proper amount of work, and to do it at the right time. If the digestive organs should begin to work when nothing had been eaten, their work would be useless. If the sweat glands should begin to pour out sweat on the skin when the body was not hot, their work would be not only useless, but even harmful. If all the muscles should begin to pull and jerk without any order or system (as they do in convulsions), they would succeed only in throwing the body to the ground.

The ruler of the body is the *nervous system.* When we walk, it is the nervous system that causes the right muscles to move. When we eat, the nervous system sets the digestive organs to work. It keeps the heart and lungs going, and governs all the body. *The function of the nervous system is to govern all the organs of the body, and to cause them all to work together for the common good.*

The Divisions of the Nervous System. The nervous system has two great divisions, — the *central nervous system* and the *sympathetic nervous system.* The great centers of the central nervous system are the brain and the spinal cord. The central nervous system controls the *voluntary*

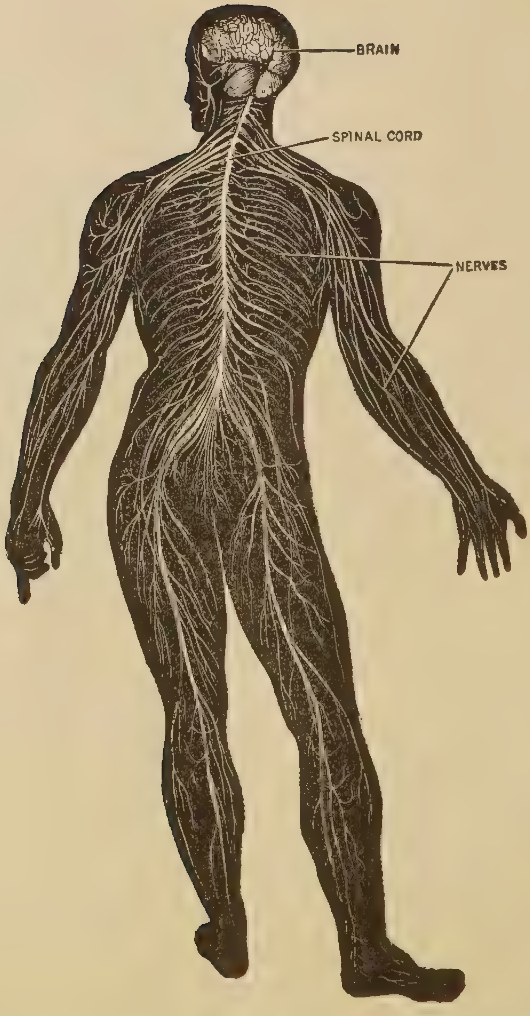


FIG. 12. The nervous system. From the brain and spinal cord, nerves run to all parts of the body.

muscles (those which we can move when we wish), and *the higher centers of the brain act as the organ of the mind.*

The sympathetic nervous system controls the glands[1] of the body and the *involuntary muscles* (page 226), — the muscles which we cannot control by the will, as those of the stomach, intestine, heart, and blood vessels.

The Brain and the Spinal Cord. The brain has three divisions, — the *cerebrum*, the *cerebellum*, and the *medulla oblongata.* The spinal cord is the soft white substance that you

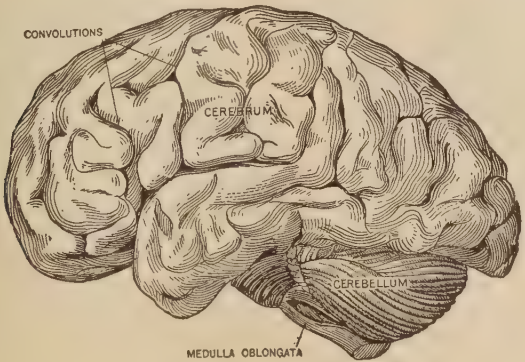


FIG. 13. The brain.

may have seen in the backbone of an animal. In man it is about seventeen inches long and half an inch in diameter. At the base of the skull is a great opening, through which the spinal cord enters the cranium (Fig. 14) and joins the brain.

The Membranes of the Brain and Cord. Around the brain and cord are three connective tissue membranes. The outermost membrane, which is thick and tough, is called

[1] The salivary glands, glands of the stomach and intestine, the pancreas, liver, kidneys, and sweat glands are some of the glands in the body.

the *dura mater.* It lines the entire dorsal cavity of the body, both the cavity of the cranium and the cavity in the spinal column. The innermost membrane, which is thin and delicate, is called the *pia mater.* It lies close to the surface of the cord and brain and dips down into all the wrinkles and folds in the surface of the brain. In it are the blood vessels that nourish the outer parts of the brain and cord. Between the dura mater and the pia mater is a third membrane, the *arachnoid membrane.* These membranes[1] hold the very soft and delicate brain and cord in place and keep them from being shaken about within the dorsal cavity.

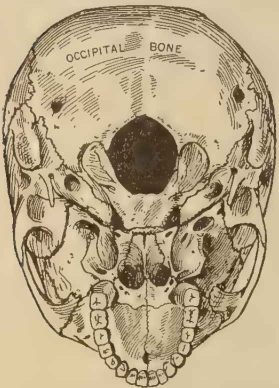


FIG. 14. The base of the skull, showing the opening through which the spinal cord enters the cranium.

The Cerebro-spinal Fluid. The brain and spinal cord are still further protected by a layer of liquid around them called the *cerebro-spinal fluid.* This fluid is on both sides of the arachnoid membrane — that is, between the dura mater and the pia mater — and entirely surrounds the cord and brain. It acts as a cushion inside the walls of the dorsal cavity and keeps the brain and cord from striking against the walls of the cavity.

Nerves. From the under surface of the brain and from the spinal cord, shining white nerves pass out to every part of the body. If you should examine one of these nerves under

[1] The three membranes taken together are called the *meninges* of the brain and cord. *Cerebro-spinal meningitis* is a disease caused by germs growing in these membranes and in the cerebro-spinal fluid.

a microscope, you would find that it is made of many hundreds of very fine fibers, bound together by connective tissue. Although these fibers are so slender that they cannot be seen without a microscope, some of them are of great length, the longest reaching from the spinal cord to the hands and feet.

In the larger nerve trunks the fibers are bound up in a number of bundles, which are all wrapped together in a common sheath (Fig. 15). The larger nerves divide into smaller

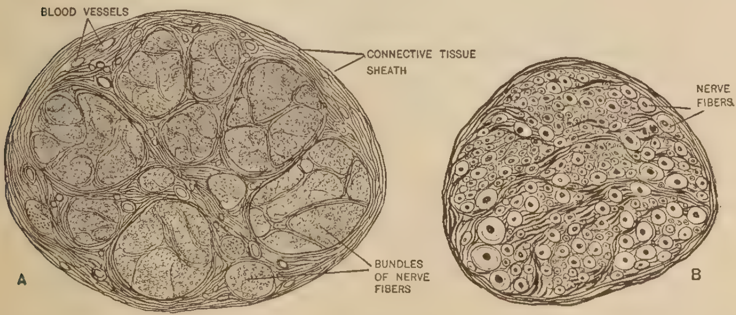


FIG. 15. *A* is a cross-section of a nerve, showing the bundles of nerve fibers that make up the nerve, wrapped in the connective tissue sheath. *B* is one of the bundles of nerve fibers shown in *A*, enlarged to show the individual fibers.

branches containing only a few bundles, or sometimes only one bundle. In the finest nerve branches, the bundles of nerve fibers finally break up into the separate fibers, many thousands of which end in the skin and muscles, and in the other organs of the body.

The Function of Nerves. *The function of the nerves is to carry messages between the different parts of the body and the brain and spinal cord.*

Some nerves carry messages *to* the brain and cord. By these messages we learn when anything touches the body,

when the body is hungry or thirsty, or hot or cold, when it is in pain, and about the things that we see, hear, taste, and smell. Other nerves carry messages outward *from* the brain and cord, causing the muscles to move, and making all the parts of the body to work together in harmony. The power by which we feel, think, and will lies in the brain. The commands that we send out, causing voluntary movements of the muscles, start from the brain. The nerves are useful only to carry to the cord and the brain messages which tell us about the body and the outside world, and to carry commands outward from the brain and cord to the muscles and to the other organs of the body.

The Telegrapher and the Telegraph Wires. The brain and spinal cord are often compared to a telegrapher in an office, and the nerves in the body to telegraph wires that run out in all directions from the office. Over the wires the telegrapher receives messages that tell him what is going on about him, and he sends out messages commanding that certain things be done. So through some of the nerves the brain and cord receive messages which tell them about the body and the things going on around it; and over other nerves they send messages out commanding the muscles to move the body, and the different organs to do their work according to the body's needs.

Necessity for a Nervous System. From this you will understand that the nervous system connects all parts of the body and causes all the organs to work together for the good of the body as a whole. Without a nervous system, the human body would not be one body at all, but a mass of flesh and blood and bones, the different organs working not at all, or working without plan or system, and the whole body certain to die in a few minutes. With a nervous system it is the living,

moving, speaking human body, the most wonderful thing in all the world.

Summary. The nervous system controls all parts of the body and causes them to work together. The great divisions of the nervous system are the central nervous system and the sympathetic nervous system. The central system controls the voluntary muscles; its chief center (the brain) is the organ of the mind. The sympathetic system controls the involuntary muscles and the glands of the body.

The brain has three divisions — the cerebrum, the cerebellum, and the medulla oblongata. Around the brain and cord, and protecting them, are three membranes — the dura mater, pia mater, and arachnoid membrane — and a layer of cerebro-spinal fluid.

Nerves are composed of nerve fibers. Nerve fibers carry messages between the different parts of the body and the brain and spinal cord. Some fibers take messages to the brain and cord, and some fibers carry messages away from the brain and cord. The nerve centers (brain and cord) may be compared to a telegrapher, and the nerve fibers to telegraph wires. The incoming messages bring information about the body and the world around the body, and the outgoing messages are commands from the nerve centers to the muscles, glands, and other organs.

Without a nervous system the different organs of the human body would work without system, or would not work at all, and the body would die. By the nervous system, all the body parts are made to work harmoniously together, — all are united into one wonderful body.

QUESTIONS

What is the function of the nervous system? Name the two divisions of the nervous system. What are the chief centers of the central nervous system? What is one of the great functions of this system? With what part of the nervous system is the mind associated? What is the function of the sympathetic nervous system?

Name the three divisions of the brain. Name the three membranes that are around the spinal cord and brain. What is the function of these membranes? What is between the arachnoid membrane and the pia mater? What is its function?

Describe the structure of a nerve. How long are the longest nerve fibers in the body? What is the function of a nerve?

In comparing the nervous system to a telegrapher and a telegraph system, what part of the nervous system corresponds to the telegrapher? What is the function of this part of the nervous system? What part of the nervous system corresponds to the telegraph wires? What is the function of this part of the nervous system?

To what part of the body are the incoming messages carried? What is the effect of these messages? To what organs are the outgoing messages taken? What is the effect of these messages?

Why is a nervous system necessary in the body?

Why is it possible for a tree to live without a nervous system, when a man cannot do so? If the cells in the human brain should become cold, would they die? Do the cells in the feet or ears die if they become cold? If a fish should be frozen in the ice, would the cells of its brain be killed? Are little one-celled animals killed by cold water? Ask a physician which cells in the body are most affected by such poisons as strychnin, opium, nicotine (the poison in tobacco), and alcohol.

CHAPTER IV

THE SKELETON

THE skeleton is the framework on which the body is built. The shape of the body, therefore, is determined principally by the skeleton. Examine your own body, and you will readily understand that this is true. Feel your head, and under your hair and skin you will find the bones which give the head its form. In the fingers and toes are bones which determine whether they shall be long and slender, or short and thick. Down the middle of your back you can feel a row of bones under the skin, and so through all the body you will find bones under the skin and muscles, outlining the forms of the different parts.

The Functions of the Skeleton. *The first function of the skeleton is to support the body.* Without a skeleton, the body would be weak and soft, and the head, arms, legs, and trunk would fall together in a confused mass. But the bones are hard and stiff, and form a strong framework, so that each part of the body stays in its proper place, and the whole body can stand upright.

The second function of the skeleton is to protect parts of the body that are easily injured. The bones of the head form a strong box to protect the brain; the spinal column holds the spinal cord safe in the cavity in its center; and the bones of the chest protect the heart and lungs.

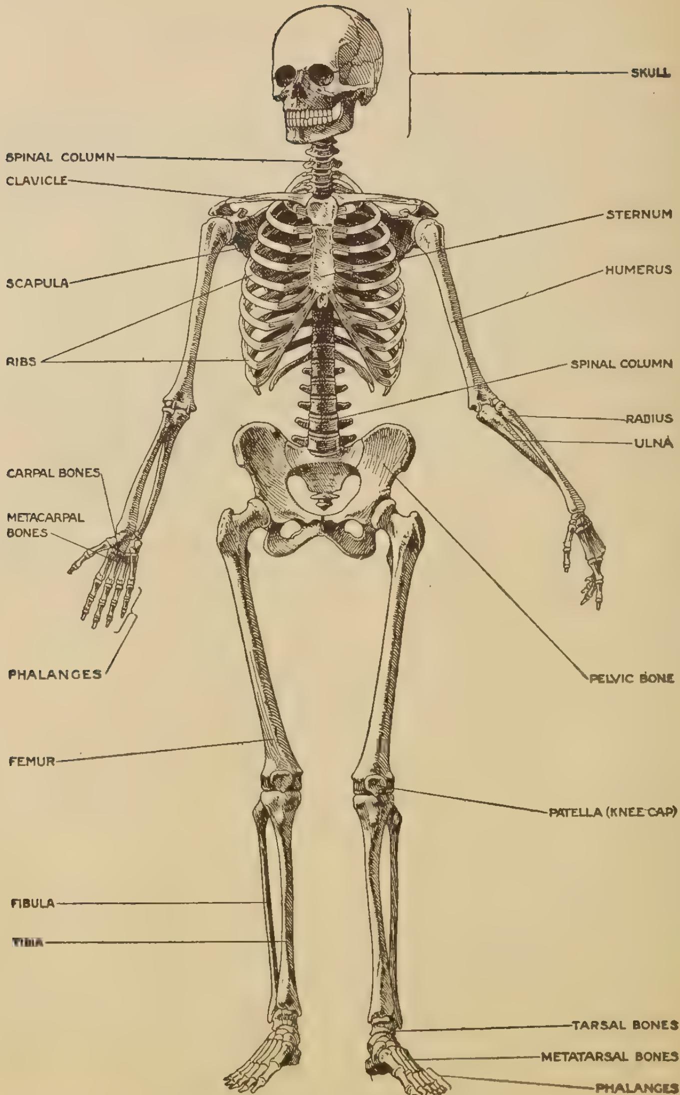


FIG. 16. The skeleton of the human body.

The third function of the skeleton is to provide a system of levers, by means of which the body can be moved. Moving the body is the special function of the muscles, and we shall take up this subject in the next chapter. But you can easily understand that without a skeleton such movements as walking or raising the arm would be impossible.

THE PRINCIPAL BONES OF THE SKELETON

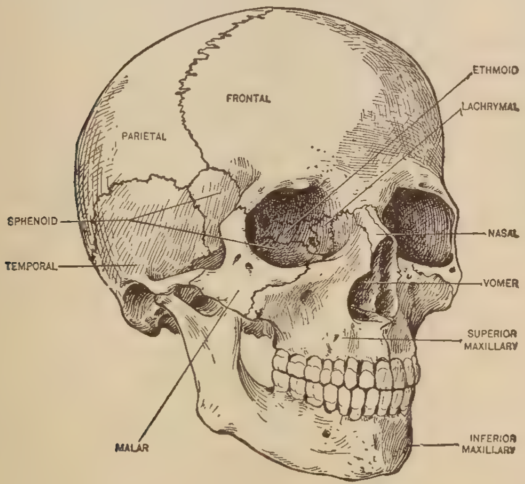


FIG. 17. The skull.

There are *two hundred and six* bones in the human skeleton. They are divided naturally into three groups. The first group contains the twenty-eight bones of the head, the second group the fifty-eight bones of the trunk, and the third group the one hundred and twenty bones of the limbs.

The Skull. The twenty-eight bones of the head taken together compose the *skull.* Eight of these bones are solidly

united to form a box (the *cranium*) for the protection of the brain. Six little bones are in the ears (Fig. 120), and the other fourteen bones of the skull form the skeleton of the face. All the bones of the face are in pairs except the lower jawbone and the thin bone which forms the partition between the two sides of the nose.

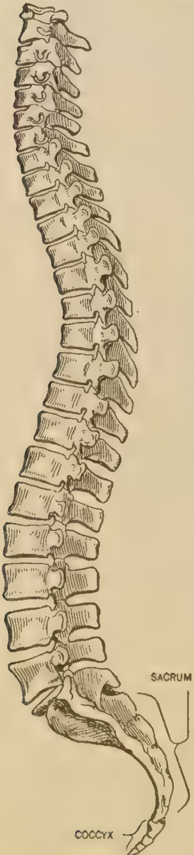


FIG. 18. The spinal column.

The Spinal Column. The spinal column is composed of twenty-four *vertebræ* (singular, *vertebra*), the *sacrum*, and the *coccyx*. *It supports the parts of the body above the hips, and protects the spinal cord.* When it is broken, standing or walking is impossible, because the trunk has no support, and because the spinal cord, through which the muscles that keep the body erect are governed, is injured.

To do its work, the spinal column must have strength enough to carry the weight of the trunk, head, and arms, and must bend easily in all directions, yet not sharply enough at any one point to crush the delicate spinal cord within it. If it were composed of long bones, either it would be stiff and allow little movement of the upper parts of the body, or it would bend sharply at the joints as the arms do at the elbows and the legs at the knees, and injure the cord at these points. But because the spinal column is composed of many short bones, and has many joints, it allows the body to bend freely forward or backward, or from side to side, yielding a little at

each joint, but not enough anywhere to crush the cord. Also, because the spinal column is flexible, bending at so many different points, it rarely happens that it is broken, as would be the case if the trunk were carried on a stiff support.

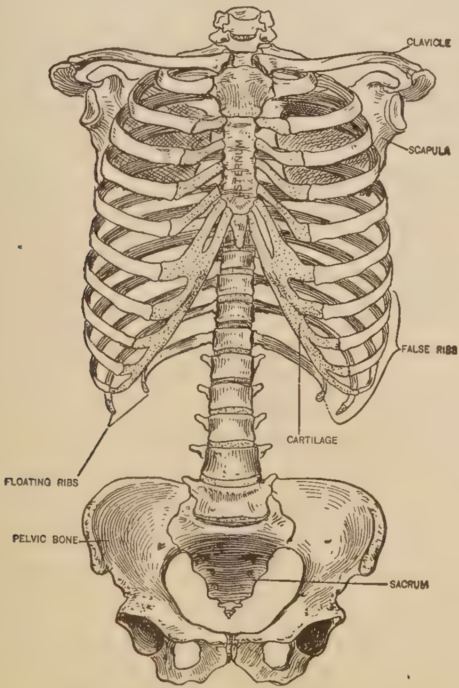


FIG. 19. The bones of the trunk.

The Sternum and Ribs. The *sternum*, or breast bone, is a flat bone lying in the front of the chest. The *ribs* are long, slender bones, which curve around the chest. They are twenty-four in number, — twelve pairs. All the ribs are joined

to the vertebræ at the back. The seven upper pairs are joined to the sternum in front, and are called *true* ribs. The five lower pairs of ribs are called the *false* ribs. The three upper pairs of false ribs have their front ends attached to the lowest pair of true ribs. The two lowest pairs of false ribs are called *floating* ribs, because their front ends are free. The ribs protect the heart, lungs, stomach, liver, and other organs lying in the upper part of the ventral cavity, and form a framework to which the muscles that are used in breathing are attached.

The Bones of the Shoulder. The *clavicle* (collar bone) and the *scapula* (shoulder blade) form the skeleton of the shoulder. The scapula lies in the back of the shoulder. In its outer end is a socket for the upper end of the arm bone. The weight of the arm, and of anything which is lifted by the arm, pulls downward on the scapula. The scapula, therefore, has powerful ligaments and muscles attaching it to the ribs and to the vertebræ, and holding it in place.

The inner end of the clavicle is joined to the sternum, and the outer end is propped against the point of the scapula, thus bracing the shoulder. When the clavicle is broken, as often happens when one falls on the shoulder, the point of the shoulder drops downward and forward. By feeling your own shoulder, you can easily locate the clavicle running out from the sternum to the point of the shoulder, and the scapula, with its bony ridge, in the back of the shoulder.

The Pelvic Bones. Place your hands on your sides, and you will feel the two large, irregular, wide-spreading *pelvic* bones. They are firmly joined to the sacrum behind and to each other in front. These three bones with the coccyx form the *pelvis*, which balances on top of the thigh bones, and gives a firm support for the upper parts of the body. The lower

abdominal organs lie within the bowl-shaped pelvis, and are partly supported by it, and many great muscles are attached to the sacrum and to the pelvic bones.

The Bones of the Limbs. Each limb has in it thirty bones, and the bones of the arms and the legs are very similar (Fig. 33). Each has a large bone in the upper part, the *humerus* in the arm, and the *femur* in the thigh. Each has two bones in the lower part, the *radius* and the *ulna* in the forearm, and the *tibia* and *fibula* in the leg below the knee. In both the wrists and the ankles we find a group of small bones, the eight *carpal* bones in the wrist, and the seven *tarsal* bones in the ankle. In the hand beyond the carpals are five *meta-carpal* bones, each bearing a finger, and in the foot beyond the tarsals are five *metatarsal* bones, each bearing a toe. In the fingers are fourteen *phalanges*, and in the toes are fourteen *phalanges*. The arms and legs have the same number of bones in each, and in their general plan differ only in this, — the wrist has one more bone than the ankle, and at the elbow there is no bone like the *patella* (knee-cap), which protects the front of the knee.

SHAPES AND STRUCTURE OF BONES

Shapes of Bones. The bones of the human skeleton may be classified as *long* and *short*, *flat* and *cylindrical*, and *irregular*. This gives us a great variety of shapes, but it is usually easy to see some connection between the shape of a bone and its function.

Long bones give motion to distant parts of the body, and by means of the long bones great rapidity of motion through long distances can be brought about. The bones by which the hands and the feet are moved so quickly and so far are the best examples of long bones.

Short bones give free movement in various directions through short distances, and at the same time give great strength. The bones of the wrists and ankles and the vertebræ are the best examples of short bones.

FIG. 20. The scapula. This flat bone has many muscles attached to it. The ridge strengthens the bone and its end provides a point against which the clavicle can be propped.

Cylindrical bones are found where supporting some portion of the body is one of the main functions of the bone. The bones of the limbs, of the hands and the feet, and the clavicles are cylindrical bones.

Flat bones are usually either protecting bones or bones to which many muscles are attached. The sternum and the bones of the cranium are flat, protecting bones. The pelvic bones and the scapulas are bones which are spread out flat to give room for the muscles. Not only are the flat bones made so as to give as much room as possible for the muscles, but the heads of the long bones are expanded for the same purpose, and nearly all bones have elevations and processes (Fig. 21) to which muscles can be fastened. This is necessary, for there are over five hundred muscles in the body, most of which are attached to the skeleton.

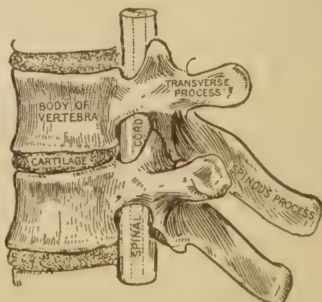


FIG. 21. Vertebræ.

Irregular bones usually have several functions. A good

example of a bone of this kind is a vertebra. This has a round portion which supports the weight of the body; it has a flattened ring of bone inclosing and protecting the spinal cord; and it has a flat spine behind and processes on the sides, to which the muscles of the back are attached.

Materials in Bone. A dead and dry bone is composed of a great network of tough fibers and of hard mineral matter that fills in the spaces between the fibers. A bone, therefore, has in it two kinds of matter, *animal* matter (the fibers) and *mineral* matter. About two thirds of the weight of the average bone is mineral matter and one third is animal matter. In childhood there is a smaller proportion of mineral matter in the bones, and in old age the amount of animal matter is very small. By the following experiments you can find out for yourself the proportion of animal and of mineral matter in a bone, and the function of each kind of material:

Weigh a piece of dry bone. Then burn it in a hot fire. Notice the smell. The animal matter in the bone is burning. When all the animal matter has been burned out, the bone will have a grayish color. When this is the case, take it out of the fire and weigh it again. Of what kind of matter is the bone now composed? What proportion of it was animal, and what proportion mineral matter? Try to bend the bone, and notice how easily it crumbles and breaks. What do you think is the function of the animal matter?

Dissolve the mineral matter out of the drumstick of a chicken or turkey by soaking it in weak hydrochloric acid.[1] Then examine the bone, and note that it is the same size and shape as before. Try to bend it and you will find that it is as limber as a piece of rubber. Of what is the bone now composed? What is the function of the mineral matter of the bone?

FIG. 22. A femur with the mineral matter removed.

[1] Any weak acid, or strong vinegar, may be used in this experiment.

From these two experiments you will understand that *the mineral matter gives to the bones the stiffness and firmness which enables them to support the body, and the animal matter gives the toughness which keeps them from breaking.*

Structure of Bones. The shafts of the long bones and a thin layer on the surface of all the bones are composed of

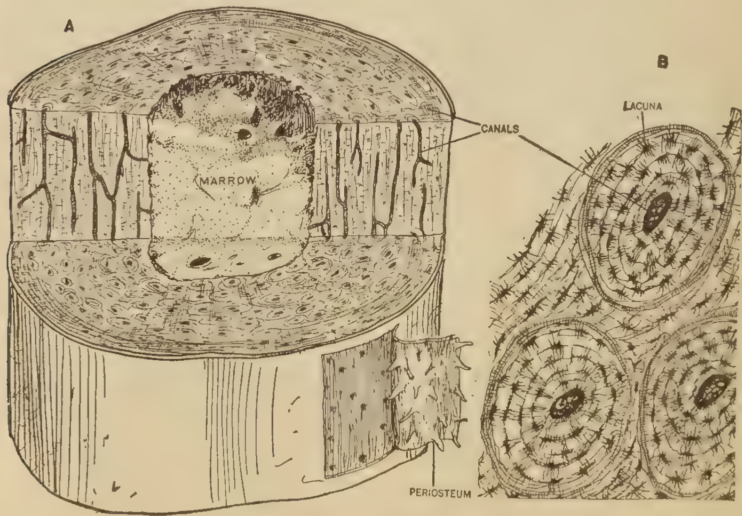


FIG. 23. *A* is a portion of the shaft of a long bone. *B* is a cross-section of a small portion of the same bone more highly magnified, showing more clearly the canals in the compact bone and the small cavities (*lacunæ*) in which the bone cells lie.

compact bone. The remainder of the skeleton is composed of *spongy* bone. The spongy bone is filled with small cavities, like the holes in a sponge. The compact bone when looked at with the unaided eye appears solid, but when examined under the microscope even this hard bone is seen to be full of very small canals. Through these canals the

blood vessels reach to every part of the bone, carrying nourishment to the bone cells.

The Cavities in the Long Bones. To provide room for the attachment of all the muscles and to have sufficient strength for the support of the body, the bones must be large. At the same time it would be objectionable to have very heavy bones, for the muscles would find great difficulty in moving them about. The small cavities in spongy and compact bone assist in decreasing the weight of the skeleton. To lighten

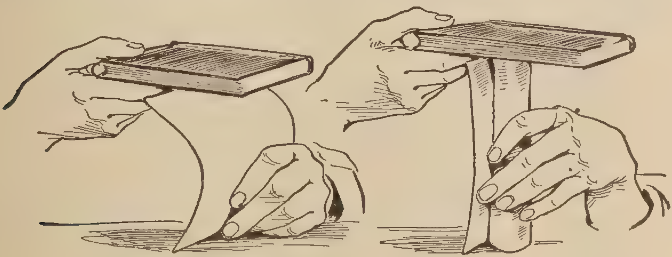


FIG. 24. Experiment showing that a hollow cylindrical bone is strong.

it still more, large cavities are hollowed out in the long bones of the limbs. That a hollow cylinder is stronger than the same material in a solid form, you can prove by the following experiment:

Set a sheet of paper on end and lay a book on it. Will it support the book? Fold the paper as tightly as possible, so that it will be in the form of a small, solid bone. Will it now support the book? Now roll the paper into a hollow cylinder and place your book upon it. Will it support a heavier weight than it would before it was rolled into this form? Does it contain any more material or is it any heavier?

Nature uses a hollow cylinder not only in the skeleton, but in other structures where she wishes to combine strength

and lightness. Stalks of grasses and grains are hollow, and so strong is a wheat stalk that it has a height four hundred times as great as its diameter, and carries the heavy head of grain without breaking, although it is blown about and bent by the wind. Man also uses hollow tubes in the framework of bicycles, and in other places where he wants strength without great weight.

Bone Marrow. The large cavities of the long bones and the smaller cavities of the spongy bone are filled with bone marrow. The marrow in the larger cavities contains blood vessels, nerves, connective tissue, and fat. The marrow of the spongy bone contains less fat, and in it the red corpuscles of the blood are formed. Because of the large quantity of fat which it contains, the marrow of the larger cavities is yellow in color; the marrow in the spongy bone, because of the large number of red corpuscles which it contains, usually has a reddish hue.

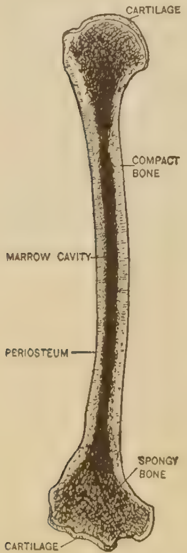


FIG. 25. Longitudinal section of the humerus.

The Periosteum. Pick the surface of a fresh bone with the point of a knife, and you can lift a thin covering or membrane. This is the *periosteum.* It is made of a network of connective tissue fibers, closely woven together over the surface of the bone. Among the fibers of the periosteum are many of the blood vessels which carry nourishment to the bones, and *if the periosteum is destroyed, the bone under it will die.*[1]

[1] A bone grows in thickness by having layers of new bone material laid down on the surface of the bone under the periosteum.

Summary. The bones support the body, protect delicate organs, and act as levers by means of which the muscles move the body. There are 206 bones in the human skeleton, — 28 in the skull, 58 in the skeleton of the trunk, and 120 in the skeleton of the limbs.

In respect to their shape, bones are classified as long and short, flat and cylindrical, and irregular. Long bones give rapid motion through long distances. Short bones combine strength and freedom of movement. Cylindrical bones are supporting bones, and flat bones protect delicate organs or have many muscles attached to them. Irregular bones usually have several different functions.

Bones are one third animal matter, which makes them tough, and two thirds mineral matter, which gives them their stiffness and rigidity. The cavities in the bones help to lighten them and at the same time permit them to retain sufficient strength to support the body.

Bone marrow contains fat, blood vessels, connective tissue, and nerves. The yellow marrow has in it much fat. The red marrow contains less fat, and in it the red blood corpuscles are formed. The periosteum carries many of the blood vessels that nourish the bone.

QUESTIONS

Give three functions of the skeleton. How many bones are in the body? Into how many groups are they divided? How many bones are there in each group?

How many bones are in the skull? in the cranium? in the ears? in the face? Name some of the bones of the skull.

How many and what bones are in the spinal column? Give two qualities that the spinal column must have. Give two advantages that come from having the spinal column composed of many parts.

Where is the sternum? How many ribs are there? What is a true rib? a false rib? a floating rib? Give two uses of the ribs.

Name the shoulder bones. To what is the scapula attached? What is the function of the clavicle? What bones compose the pelvis? Give three functions of the pelvis. Compare the skeletons of the arm and of the leg.

Give four shapes of bones, with the functions of bones having each of these shapes. Give examples of bones of each shape.

What two kinds of material in bone? What proportion of a bone is mineral matter? animal matter? What is the function of the mineral matter? of the animal matter? At what time of life is there little mineral matter in the bones? little animal matter?

Where in the skeleton is the compact bone found? spongy bone? How do compact and spongy bone differ?

Why is it necessary that the bones should have considerable size? What would be the objection to having large solid bones? How have the large bones been lightened without too greatly weakening them?

Of what is bone marrow composed? Where is red bone marrow found? yellow bone marrow? How does one kind of marrow differ from the other? What is the periosteum? What happens to the bone when the periosteum is destroyed?

Of what is the animal matter in a living bone composed (page 8)? Do the bones of an old person or of a little child bend more easily? Why? Which breaks more easily? Why? Which heals more easily after it is broken? Why?

Is a hollow iron post as strong as a solid iron post of the same size? How many times as high as its own diameter is the tallest smokestack or tower that you know?

What part of the skeleton is incomplete in a little baby?

CHAPTER V

THE SKELETON (Continued)

JOINTS

Each bone can support the part of the body in which it is located, but to form a skeleton for the support of the body as a whole, the bones must be joined together. The places where the bones come together are the *joints*. These are divided into two great classes, — immovable and movable joints.

Immovable Joints. Immovable joints are found in portions of the body where movement between the bones is not necessary, and where great strength and firmness are required in the skeleton. In the cranium all the bones are solidly joined to protect the brain, and the joints are immovable. The joint between the two pelvic bones, and the joints between the pelvic bones and the sacrum, are other examples of immovable joints. All the bones of the pelvis are thus firmly united in one solid support for the body. In our own bodies we overlook the immovable joints because there is no movement at these places, but in a skeleton this kind of joint may easily be observed.

Necessity for Movable Joints. Most of the joints in the skeleton are movable. It is necessary that they should be, for it is only at the movable joints that the body can bend. Without movable joints you could not close your hand; you

could not bring your hand to your mouth; you could not sit; and you could not walk. Without movable joints it would not be possible for one part of the body to be moved without moving the whole body. You will understand, if you think about it, that with the whole skeleton united solidly in one piece, our muscles could not move the body at all. With a skeleton having movable joints, they lift the body about, one part at a time; but without the bending at the joints, the muscles would have no more power of lifting the body than you have of lifting a chair in which you are sitting.

Kinds of Movable Joints. Movable joints are of three[1] principal kinds, — *ball-and-socket* joints, *hinge* joints, and *gliding* joints.

In ball-and-socket joints a ball, or rounded end, of one bone fits into a socket, or cup-like hollow, in the other bone. The shoulder joint and the hip joint (Fig. 27) are good examples of ball-and-socket joints. This kind of joint allows motion freely in any direction, as you can observe by swinging the arm about at the shoulder, or the leg at the hip.

Hinge joints do not allow motion in all directions, but only in two opposite directions, — the same movement that a knife blade has in opening and closing. The elbow and knee joints, the first two joints of the fingers and toes, and the joints of the lower jaw are examples of hinge joints. What kind of a joint is at the base of the metacarpal bone that bears the thumb?

In gliding joints the bones move or glide only a little on each other. The joints between the small bones of the ankles and the wrists are good examples of gliding joints.

[1] The joints between the bodies of the vertebræ are intermediate between immovable and movable joints. In them the bones do not slide on each other, but the thick and elastic cartilages (Fig. 21) permit considerable bending.

to the brain. To prevent this jarring, the skeleton has in it three devices that give springiness to the whole frame.

The Arch of the Foot. Press on a curved stick or a piece of barrel hoop as shown in Figure 28, and notice how much springiness the arch gives it. The bones of the human foot form an arch on which the weight of the body falls when the body is in a standing position. In walking and running, therefore, the arch of the foot acts as a spring under the body.

FIG. 30. This straight stick jars the hand.

FIG. 31. This curved stick springs down and does not jar the hand.

The Curves of the Spinal Column. Strike the floor with a straight stick held as in Figure 30 and your hand will be jarred. But strike the floor with a curved stick held in the same way, and you will find that the curve will give a springiness to the stick that prevents the hand from being jarred. The double curve of the spinal column (Fig. 18) makes it springy, and so protects the head from the jar when the feet strike the ground. You can get an idea of the usefulness of these curves by imagining how much worse your brain would be shaken up when you run and jump if your head were carried on the end of a straight, stiff bone instead of on your spinal column.[1]

[1] Jump with the legs held straight and stiff. Then jump with the legs bent at the knees, and notice the difference in the amount of jar the body receives.

Cartilages. The cartilages between all the joints, but especially the thick cartilages between the vertebræ (Fig. 21), act like rubber pads in giving elasticity to the skeleton. If you have worn shoes with rubber heels, or have walked on a rubber mat, you will know at once how these cartilages prevent jarring of the brain.

These three devices, along with the half-bent joints of the legs, give springiness to the skeleton and protect the brain. How well this work is done, you may know from the fact that boys and girls in their play run about and jump, and sometimes fall so hard that the bones of the body are broken, and yet it is not often that the brain is injured.

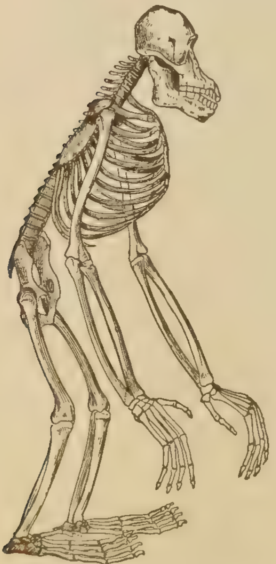


FIG. 32.
Skeleton of an orang-utan.

THE SKELETONS OF OTHER VERTEBRATES

Similarity of Human and Other Vertebrate Skeletons. In the skeletons of all vertebrates, a spinal column and skull are found. All of them except the amphibians have ribs. Shoulder and pelvic bones to which the limbs are attached are found in almost all of them. The limbs of vertebrates are built on the same general plan, but they are used in so many different ways that the skeletons of the limbs may seem to be very different. Certain bones may be much longer than they are in man, as the phalanges in the wings of a bat.

Often bones may be united as are the tibia and the fibula in the frog, and the carpal and metacarpal, and the tarsal and metatarsal bones of many animals. Sometimes we have the wrong idea of a limb until we study it closely. Thus, in the front limb of the horse, the foot corresponds to one finger on our hand, the hoof to a finger nail, and the one metatarsal is very long, so that what seems to be the knee is really the wrist. In birds the tarsal and metatarsal bones are united and elongated and in a chicken the ankle joint is often thought to be the knee. In some ways the limbs of these animals are very different from the limbs of man, but all the principal bones in them correspond to the principal bones in the human arms and legs.

Differences between the Human and Other Vertebrate Skeletons. Of all the vertebrates, monkeys and apes have skeletons most nearly like the skeleton of man. But although an ape's skeleton has in it every bone that is found in the human skeleton, yet there is no difficulty in distinguishing between the two.

An ape has less intelligence than a man, and its brain and cranium are much smaller. The jaws of an ape are much longer and heavier than they are in man, the teeth are larger, and the front teeth slant forward.

The human spinal column has a backward turn at the top that causes the skull to balance on top of the spinal column when the body stands upright. The spinal column of an ape lacks this backward curve, and when an ape stands up its head sticks out forward. The muscles of the neck, shoulders, and back, therefore, have heavy work to keep the head from falling forward when the body stands erect.

The pelvis and femurs of man are also fitted for an upright carriage of the body. Man is a very tall animal for his size,

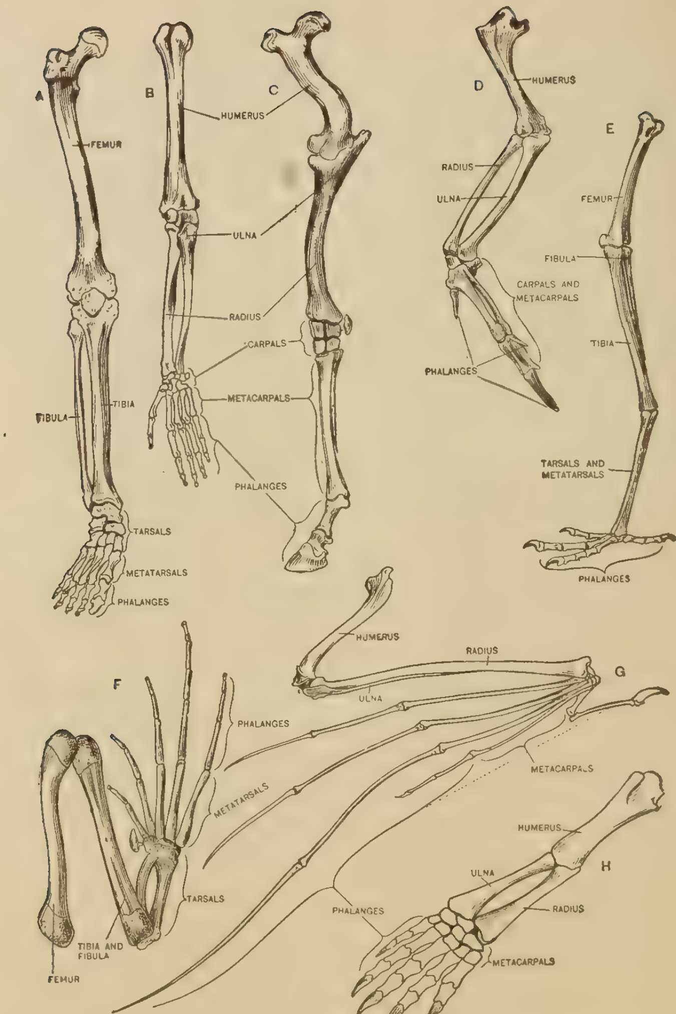


FIG. 33. Vertebrate limbs. *A* is the human leg; *B*, the human arm; *C*, the fore leg of a horse; *D*, the wing of a bird; *E*, the foot of a bird; *F*, the hind leg of a frog; *G*, the wing of a bat; *H*, the fore leg of a tortoise.

and he has only two feet to balance himself on. The human pelvis is, therefore, wide, and the heads of the femurs are turned inward. The feet are thus spread apart, making it easier to keep the balance of the body. Shut your eyes and stand with your feet wide apart. Then shut your eyes and stand with your feet close together, and you will understand the advantage of this arrangement.

The arms of the ape are proportionately much longer than the arms of man, and the legs are shorter. In man the arms reach about halfway between the hip and the knee. In apes they reach to the knee, and in some species even to the ground.

In apes all the metacarpal and metatarsal bones are very long except the first one, which is very short. This sets the thumbs and great toes far down on the sides of the hands and feet, and in reality gives the apes neither true hands (with thumbs opposing the fingers) for grasping, nor feet for walking, as we find in man; but long organs halfway between hands and feet, with which the ape holds to large branches as it climbs among the trees.

HYGIENE OF THE SKELETON

As the body grows, mineral matter is gradually deposited in the bones and the skeleton becomes harder. During childhood the bones are flexible and it is easy to bend them and change their shapes; but after the skeleton has hardened, it is exceedingly difficult to change the shape of the bones.

It is very important, therefore, that the skeleton be kept in proper position during childhood and youth. The general carriage of the body cannot be well understood until we have studied the muscles, so here we shall point out only

a few ways in which different bones of the body may be bent out of their proper shape.

Allowing a baby to stand up and walk too soon may cause him to become bow-legged, and lifting or carrying heavy loads may have the same effect on older children. Heavy work done by the young is likely to pull the points of the shoulders downward and forward, causing round shoulders. Anything carried habitually on one side may cause the spinal column to be bent over to that side. It has been found that many school children have slight curvature of the spine from always carrying their books on the same arm, and very many people have one shoulder or hip a little higher than the other. Boys sometimes wear belts that are drawn too tight around the waist, instead of resting on the hips. These, or any tight clothing around the waist, may bend in the lower ribs. This is very injurious, for it presses on the organs which are packed in the abdominal cavity.

You should avoid all these unhygienic practices, and others which you will think of for yourselves, such as stooping over your desk, or sitting sideways in your seat with one shoulder higher[1] than the other, while you study or write. You should take especial care to form the habit of carrying the body erect; for if the bones are permitted to harden in a stooping position, it is almost certain that you will go through

[1] To the Teacher: Much real damage as well as a great deal of discomfort may be caused by having seats and desks that are too low or too high for the pupils. Writing on desks that are too high will throw one shoulder higher than the other and cause lateral curvature of the spine. Bending over a desk that is too low will give a stooping carriage to the body. Sitting in seats so high that the feet cannot touch the floor causes stooping and very great weariness. Where the school authorities fail to provide proper desks, the teacher should see that the younger children have foot rests and should do everything in his power to have all his pupils properly seated.

life with a stooping carriage, your sternum and ribs dropping down and crowding your heart and lungs. If you have any work that compels you to stoop as you do it, stop once in a while, straighten yourself up, and take several deep breaths; in addition, make a special point of holding the body erect while not at work.

Broken Bones. If the two ends of a broken bone are placed together, the bone cells soon cover the surface of the broken ends with a jelly-like, white material. In a few days this begins to harden, and soon the two parts are firmly united. The only thing we can do to help nature in this process is to put the broken ends together, and keep them together until the fracture is healed. Of course a physician must be called to set a broken bone, but the patient needs intelligent care until the physician arrives. If an arm or a leg is broken, stretch it out straight on a pillow. If the person must be moved, tie a pillow about the limb, or wrap a blanket or a coat around it, and then tie umbrellas or canes about it to keep it straight. Often there are sharp points on the broken ends of bones. In lifting the person, *take care that the limb is not bent at the fracture*, or the sharp ends of the broken bone may cut the muscles, blood vessels, or nerves.

Dislocations and Sprains. When the ligaments (and sometimes the muscles and nerves also) around a joint are broken, and the bones slip out of place, we have a *dislocation*. A few people have some joints with sockets so shallow that the bones may be dislocated without breaking the ligaments, but such joints are not common. When a bone is dislocated, it must be put back into its place and kept there until the ligaments grow again about the joint. Usually only a physician can get a dislocated bone back into place without danger to

the patient, and he should be called before the parts become swollen.

When a joint is *sprained*, some of the ligaments around it are broken and torn loose, but the bones are not dislocated.

Treatment of Dislocations and Sprains. Until a physician can be called, both dislocated and sprained joints should be bathed in either hot or cold water, or, better still, in hot and cold water alternately. This will help to keep the injured part from swelling and becoming painful.

A dislocated or sprained joint should not be rested all the time, but should be exercised, even if the movement causes great pain. If the joint is not exercised, it will become much swollen with liquids from the blood, and will be very painful. Exercise helps to keep up a good circulation of the blood through the part, and this carries away the broken tissue and dead cells, and helps in every way to hasten the healing of the injury. But after a dislocation, great care must be used that, in exercising, the injured parts are not again dislocated. A dislocated joint should be well bandaged to keep the bones in place, and then exercised in such a way that there will be no danger of dislocating it again.

Tobacco and the Skeleton. The bones are built up and grow through the manufacture of bone materials by the cells (page 8). Tobacco seems to injure the cells which do this work, for young persons who use tobacco are usually stunted in their growth. We know that tobacco injures the heart and the digestive organs, and it may be that it injures the bone cells by preventing them from getting a good supply of food and oxygen. Possibly the tobacco itself injures the bone cells. However the harm is done, we are sure that it is done, for the bones of young tobacco users do not grow as they should

Summary. There are two great classes of joints, im

movable and movable. Immovable joints are found in the skeleton where motion is not necessary, but firmness and strength are required. Movable joints are necessary that the different body parts may have motion. The three principal kinds of movable joints are ball-and-socket joints, hinge joints, and gliding joints.

The ends of the bones are covered with a smooth, white substance called cartilage. In the movable joints this is kept moist with an oil-like liquid, which causes the joints to work smoothly. At the joints the bones are tied together with strong connective tissue ligaments.

The arch of the foot, the curves of the spinal column, and the cartilages in the skeleton and the half-bent knee joints keep the brain from being jarred as we walk and run.

The human skeleton resembles other vertebrate skeletons in having a spinal column, skull, ribs, shoulder and pelvic bones, and two pairs of limbs. The bones in other vertebrate limbs often differ markedly from the bones in the human limbs, but in all these limbs the same general plan of the skeleton is present. Man's skeleton differs from an ape's in the skull, spinal column, pelvis, and femurs, the length of the arms, and in the hands and feet.

During childhood and youth the bones are easily bent, and it is very important that they be kept in proper position. A broken limb should not be allowed to bend at the fracture. In a dislocation or a sprain the ligaments about the joint are broken. A joint that has been injured in this way should be treated with hot or cold water and carefully exercised.

Tobacco keeps the bones of the skeleton from reaching their full growth.

QUESTIONS

What is a joint? What are the two great classes of joints? Where are immovable joints found? Give examples of immovable joints.

Why are movable joints necessary? Name three kinds of movable joints. Explain what movement each kind of movable joint allows. Give examples of each kind.

Where is cartilage found? What is its use in the movable joints? What is a ligament and what is its function?

Why is it important that the skeleton should have springiness? Name three devices for giving springiness to the skeleton.

Mention some ways in which the human skeleton resembles other vertebrate skeletons. Mention five ways in which the human skeleton differs from the skeleton of an ape.

Why is it important that the skeleton be kept in proper shape during early life? Mention four ways in which parts of the skeleton may be deformed.

How would you care for a person with a fractured limb? What is a dislocation? a sprain? What is the best treatment for a dislocation or a sprain?

What effect has tobacco on the skeleton?

Carefully measure your height in the morning. Then measure it again at night after you have been moving about all day. Are you taller in the morning or in the evening? Why?

Do you know any animals that have the skeleton on the outside of the body? What great advantage is this to these animals? What do crabs, lobsters, crayfish, and many insects find it necessary to do when the body increases in size? An earthworm has no skeleton. How does it cause its body to move in crawling?

CHAPTER VI

THE MUSCLES

THE skeleton supports the body. *The muscles move it.* When we think of a living animal, we think of it as having the power to move. Yet without muscles we and all the animals we see about us would lie quiet, like dead matter. It is by the power of the muscles that the giant whale is driven through the sea, and the wild bird is carried through the air. Muscles cause the wings of the mosquito to vibrate faster than the eye can see; they move the creeping snail. The muscles carry our feet along, they lift our arms, they keep our hearts beating night and day. *The power by which a muscle causes movement lies within its cells.*[1]

The Muscles. The skeleton is the framework of the body, and the muscles are stretched on the framework, sliding smoothly and noiselessly over one another in their movements. They form the chief part of the flesh which rounds

[1] The tissues that we have studied up to this time are the *supporting tissues* of the body, and the pupil should get clearly in mind the difference between them and the other tissues. The function of bone, cartilage, and connective tissue is to support the body. Since this work is too heavy for soft cells, the cells of supporting tissues become builders and construct a great framework to support the body. The bone cells build bone fibers and hard mineral matter. The connective tissue cells build tough connective tissue fibers, and the cartilage cells build the groundwork of cartilage. *Supporting tissues are composed of cells and materials which the cells have built. Other tissues are composed entirely of cells.* Muscle tissue is composed of muscle cells, the largest and most active cells in the body.

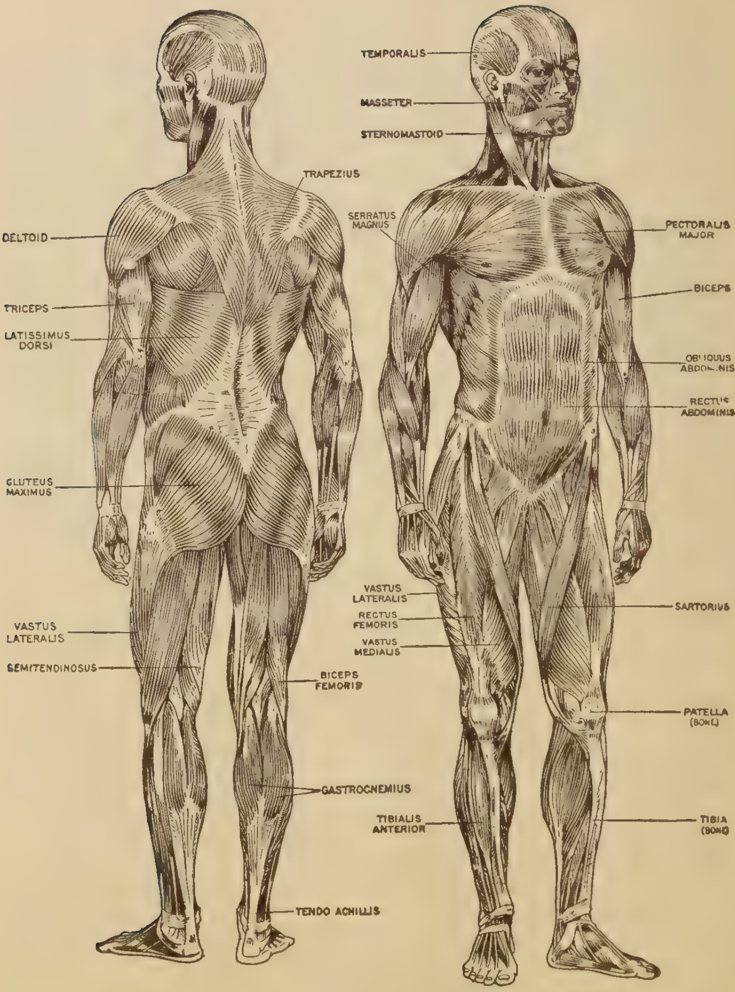


FIG. 34. The outer muscles of the body.

out the body. They number more than five hundred, and more than two fifths of the entire body weight is muscle. The lean meat of animals is muscle, and by examining the body of an animal in a butcher shop, you can see that a great portion of the entire body is composed of muscles.

The Functions of Muscles. *The first and chief function of the muscles is to move the body.* The muscles cause the movements when we walk or run, when we turn the head or eyes, when we swallow, when we breathe, or when the heart beats. The body cannot move in any way except by means of the muscles.

The second function of the muscles is to help the bones inclose the body cavities, and thus protect the delicate internal organs.

The third function of the muscles is to assist the ligaments in binding the skeleton together at the joints. Nearly every muscle in the body stretches across a joint and is attached on each side of it, and the strong muscles are a great aid in holding the skeleton together.

How the Muscles move the Body. Muscle cells [1] are so long that they are often spoken of as muscle fibers. They have the power of contracting, or of drawing up and becoming shorter and thicker, as a worm does in crawling. When the

[1] The cells of voluntary and involuntary muscles are very different in appearance. Involuntary muscle cells (Fig. 5) are spindle-shaped, and are several times as long as the average body cell. Voluntary muscle cells (Fig. 35) are slender fibers often two and a half inches long, which is many hundreds of times longer than an ordinary cell (see footnote on page 4). An involuntary muscle cell, like an ordinary cell, has only one nucleus. A voluntary muscle cell has thousands of nuclei. The reason for this is that the nucleus is the part of the protoplasm that enables the cell to take in and use food, and one nucleus would not be enough for a cell containing the great amount of protoplasm found in a voluntary muscle cell.

cells in a muscle contract, the whole muscle is shortened. This causes a bending at the joint over which the muscle passes, and a movement of some part of the body, since the muscle pulls on the bones to which it is attached. From Figure 39 you can understand how, when the biceps muscle contracts, the arm is bent at the elbow and the hand raised.

Voluntary and Involuntary Muscles. Muscles are divided into two great classes, — *voluntary* and *involuntary* muscles. *Voluntary muscles are under the control of the will.* They are governed by the brain, and we can contract them when we wish. Try to raise your hand and you can do so, because it is moved by voluntary muscles. Nearly 'all the voluntary muscles are attached to the skeleton.

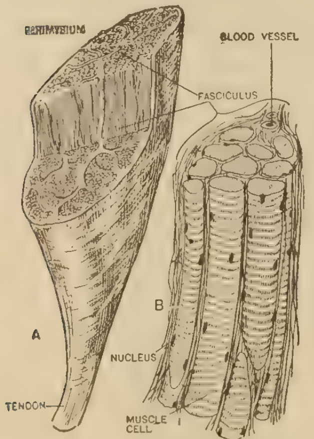


FIG. 35. *A* is a portion of a muscle showing the connective tissue covering (perimysium) and the connective tissue partitions which divide the muscles into bundles of muscle cells (fasciculi). In *B* a part of a bundle of cells is shown more highly magnified. The length of the muscle cells is so great that only a small portion of any one cell can be shown.

Involuntary muscles are not under the control of the will. They are governed by the sympathetic nervous system, and over them the will has no control. If food were started down your throat, you would be compelled to swallow it even though you knew it contained poison, for the muscles of the throat are involuntary muscles. The involuntary muscles are found chiefly in the blood vessels, walls of the heart, digestive organs, and in other internal parts of the body.

The Connective Tissue Skeleton of Muscles. The muscles are held together by connective tissue, and the arrangement of this tissue in a voluntary muscle is very similar to its arrangement in a nerve. A muscle has a connective tissue sheath, which covers it like a thin skin (Fig. 35). Connective tissue partitions[1] run in from the sheath all through the muscle, dividing the muscle cells into groups and tying them up into bundles. Fine fibers of connective tissue are woven in among the individual muscle cells, so that the muscle has around it, and running all through it, a framework of connective tissue.[2] The connective tissue passes out at the ends of a muscle and, becoming entangled and interwoven with the fibers of the periosteum, attaches the muscle to the skeleton (Fig. 36).

Tendons. The connective tissue may pass directly from the muscle into the periosteum of the bone. Often, however, the connective tissue from a muscle unites and forms a tough white

FIG. 36. Diagram showing how the connective tissue passes through a muscle from bone to bone. The muscle cells are shown many times larger than they would actually appear.

[1] In a piece of meat cut "across the grain" (*i.e.* across the muscle cells) the connective tissue partitions in the muscle may easily be seen.

[2] Not only the muscles, but the whole body has a complete framework of connective tissue. If all materials of the body except the connective tissue were removed, there would still remain the form of the whole with all the organs in place.

cord called a *tendon*. The tendon passes to a bone — sometimes to a bone at a considerable distance from the muscle — and attaches itself to the bone by spreading out on its surface and sending its fibers in among the fibers of the periosteum.

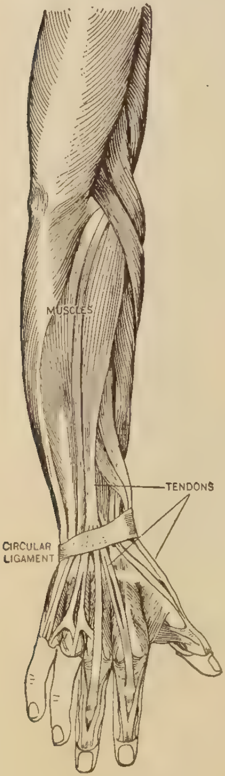


FIG. 37. The muscles of the forearm and the tendons and ligaments of the hand and wrist.

Uses of Tendons. Certain parts of the body (the hands, for example) need to have great strength and to be capable of making a variety of movements, without at the same time becoming so covered with muscles that they will be large and heavy. In such parts of the body, the muscles are placed at a distance and joined to the bones by tendons. There are nearly thirty muscles for moving the fingers of each hand. If all these muscles were on the hand, it would not be very beautiful, and would be too clumsy to do any fine work. The muscles that move the fingers are, therefore, placed on the forearm, and only slender tendons run down to the hand. Open and close your hand, and you can see and feel the muscles working in your forearm, and in the wrist and back of the hand you can see the movements of the tendons which close and open the fingers.

Tendons held in Place by Ligaments. In Figure 37 you can see that the tendons pass under strong ligaments which surround the wrist. In many other parts of the body there are ligaments forming

bands and loops, which hold the tendons down close to the bones. You can learn the necessity for these ligaments by an experiment, and the same experiment will teach you something about tendons.

Tie a piece of string about the tip of the first or second finger. Run the string back along the front of the finger, across the palm, and up the wrist to the forearm. This string is to represent a tendon. Now get one of your schoolmates to tie strings around your finger, hand, and wrist, as you see in Figure 38. These strings represent the ligaments which hold the tendons in place. From up on the forearm pull on the cord which represents the tendon. What effect has it on the finger and hand? Cut the cords which represent the ligaments, and pull on the cord representing the tendon as before. Does the cord follow the curves of the fingers and hand, and lie down flat along the bones? What difficulty would we have in the hand if the tendons were not tied down to the bones? Now turn the string about and run it down the back of the finger and hand, and note how a tendon pulling on the back of the finger will open it.

From this experiment you will understand the use of the ligaments in the hand and wrist; you will also realize that without the ligaments around the ankles, the tendons would rise and run straight from the toes to the muscles below the knees; and that all through the body it is very necessary for the tendons to be tied down close to the skeleton.

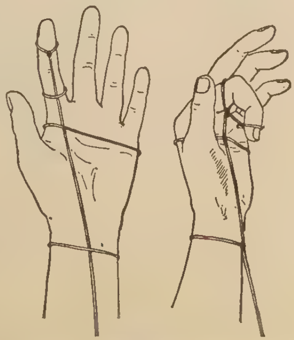


Fig. 38. Illustrating how a tendon bends a finger.

Constant Contraction of Muscles. Lay the back of your hand on the desk, stiffen your arm at the elbow, and bear down on the desk. Now feel the muscle on the back of your upper arm. It is hard and contracted. It is keeping your arm from bending by pulling on

the point of the ulna at the elbow. Now stand on one leg with the knee of that leg slightly bent, and feel the muscles both above and below the knee. They are tightly contracted because they are holding the knee and ankle joints from giving way under the weight of the body.

You know that if a man goes to sleep when sitting up, his head falls forward. The muscles which support the head must keep a constant contraction to hold it erect, and when the man goes to sleep these muscles relax. A dead body will not stand up, but will give way at the joints. The living body can stand up because the muscles keep the body from bending at the ankles, knees, hips, and in the back. Not only when the body moves, but when any part of it is held erect or extended, the muscles must be contracted to hold it in position. Try holding the arm extended for five minutes, or standing perfectly still for some time, and you will soon find that some of your muscles are doing heavy work, although there is no movement of the body.

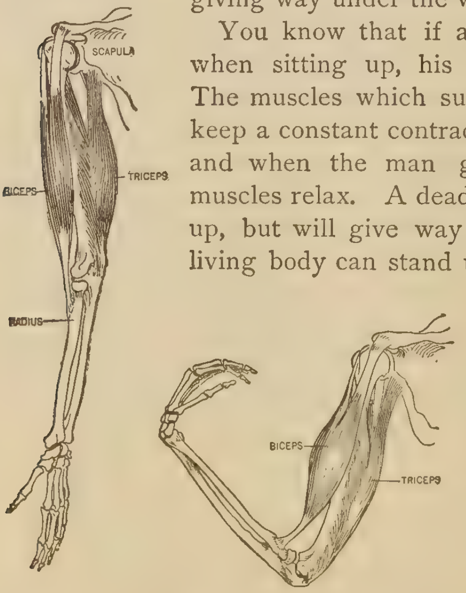


FIG. 39. The antagonistic action of the biceps and triceps muscles.

Antagonistic Muscles. Many of the muscles of the body are in pairs, each muscle of the pair working against the other. Muscles which oppose each other in this way are

called *antagonistic muscles.* An excellent example of a pair of antagonistic muscles is found in the upper arm. On the front is the *biceps*, which lifts up the forearm. On the back of the arm is the *triceps*, which straightens out the forearm. In the leg, both above and below the knee, other antagonistic muscles will be found, and as you study the muscles of the body, you will note that nearly all of them are arranged to work in opposition to other muscles. This is necessary, *for a muscle cannot push*, and if a part of the body is to be moved back and forth, it must have a muscle to pull it each way.

Accuracy of Motion given by Antagonistic Muscles. The antagonistic action of muscles is very important in giving us control of our movements. Suppose you wish to extend the forearm to pick up something. You do this by contracting the triceps. If there were no biceps, the forearm would be thrown out with a jerk, and would probably go beyond the object for which you were reaching. But as the muscles are arranged, the biceps exerts a steady, even pull against the triceps, and when the hand has been extended far enough, the biceps gives a pull strong enough to balance the action of the triceps, bringing the hand to a stop at just the right place to grasp the object. The brakes on a street car or on a railroad train make it possible to stop at the desired place. In the same way, the antagonistic action of the muscles enables us to check the movements of the body and keep them from going too far.

The Nervous Control of the Muscles. The way in which the nervous system controls all the muscles and makes them move the body about, seems almost as wonderful as a story from the *Arabian Nights*. You look at a book and wish to read in it; your hand reaches out and grasps the book, opens

it at the place where you wish to read, and holds it up before your eyes. You wish to go out of the room; your body rises, your feet carry you along, and out of the room you go. You wish to throw a ball to one of your playmates; the muscles of your legs and back, the muscles which draw back the shoulder, arm, and hand, those which draw these parts forward again, and the muscles which open the hand to release the ball, are all brought into action. Each one of this great number of muscles must contract at exactly the right time, with exactly the right force, and must not remain contracted a moment too long, or the ball will go wide of the mark, and you will make a poor throw.

All such movements are accomplished, not by each muscle working independently, but only through the nervous system, which controls them all. From the brain or spinal cord a nerve goes to every voluntary muscle in the body, and a branch of a nerve fiber goes to each muscle cell (Fig. 102). When you wish to make a certain movement, the commands pass through the nerves to the proper muscles, the muscle cells contract, and the movement is made.

The voluntary muscle cells are controlled by the central nervous system. Many commands are sent to them without our thinking about it; many movements have been made by us so often that the cord and brain send the right commands without thought. But all of the voluntary muscles[1] are under the control of the will, and when we desire to do so, we can send a message from the brain to any one of these muscles and make it contract.

[1] The muscles that are used in breathing are in a sense intermediate between the voluntary and involuntary muscles. We can control them for a short time; but if the breath is held, they soon act in spite of the will. Try holding your breath and you will find that it is possible to do so for only a short time.

THE CARRIAGE OF THE BODY

It would be interesting and profitable[1] to locate a number of the more prominent muscles of the body and to study their action, but we have time to take up only the muscles that support the spinal column. From your study of the skeleton you already understand that the entire upper part of the body stands up on the spinal column as on a stem (Fig. 19), and that if the spinal column droops, the head and the whole framework of the chest must stoop forward. It is therefore not necessary to explain to you why these muscles are so important from the hygienic standpoint.

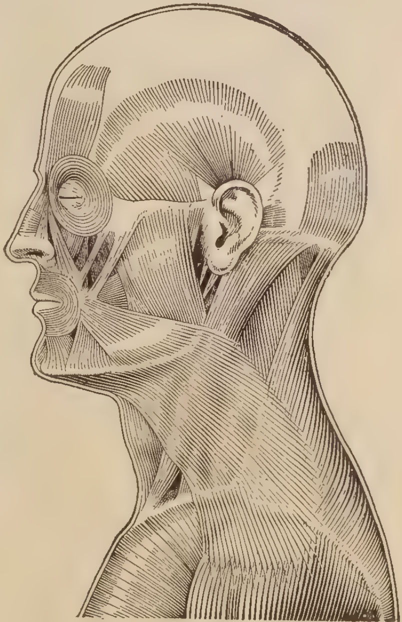


FIG. 40. The muscles of the head.

The Long Muscles of the Back. Along the dorsal side of the spinal column are long muscles for supporting the spine and for keeping the skull from falling forward. The muscles of the back are heaviest in the *lumbar region* (the "small of the back"),

[1] TO THE TEACHER: If time will permit, some exceedingly valuable work may be done by having the pupils learn the origin, insertion, and action of some of the muscles shown in Figure 34. The most interesting and profitable part of the work will be the location of these muscles on the body.

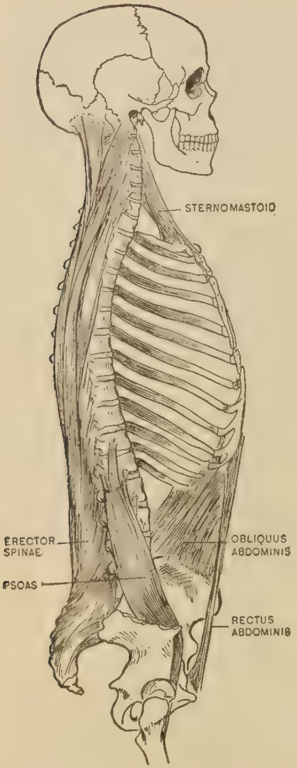


FIG. 41. The muscles that support the spinal column. It is these muscles, and not the muscles of the shoulders, that hold the body erect.

where the two large *erectors of the spine* (erector spinæ) may easily be felt on either side of the spinous processes (Fig. 21) of the vertebræ.

When the long muscles of the back contract they straighten the upper part of the spinal column, as the tendons on the backs of the fingers open the hand. When the muscles of the back are weak they allow the head and the upper part of the spine to droop forward, spoiling the appearance and allowing the framework of the chest to drop down and crowd the lungs and heart.

The Abdominal Muscles. The abdominal muscles are long, thin, flat muscles lying in the abdominal walls. These muscles connect the ribs and sternum with the rim of the pelvis and prevent the upper part of the trunk from being drawn over backward by the long muscles of the back. The abdominal muscles also hold the internal organs in place, and by forcing the internal organs back against the dorsal wall of the abdominal cavity, support the spinal column in front in the lumbar region.

The Psoas Muscles. The heavy *psoas* muscles are attached along the spinal column in the lumbar region. These muscles

have two functions. They lift the thigh, or if the leg is held so that it cannot be raised, they bend the body forward at the hips. They also *brace the spinal column on the front of the lumbar curve*, preventing too great a forward curvature at this point.

How to acquire and keep an Erect Carriage. In bringing the body to an erect position, the great thing is to straighten out the curves of the spinal column. Straighten the upper curve, and the head and chest will be lifted. Straighten the lower curve, and the abdomen will be drawn in. Teach the muscles on both sides of the spinal column to keep the proper contraction, and the body will stand erect. The easiest way of training the muscles to do this work properly is *to stand and walk as though you were hung by the top of the head*, a little back of the center. This will cause the spinal column to be straightened out, pull in the abdomen, and bring up the head until it balances on top of the spinal column. Stand in this position, and note that your head is back and your chin is close to your neck, your ribs and sternum are lifted off the heart and lungs, and the muscles are tightened across the abdomen, forcing the abdominal organs back and up. "*Stand tall," thrusting up the top of the head as high as possible, and drawing the chin and abdomen in*, is the best rule for position in standing and walking.

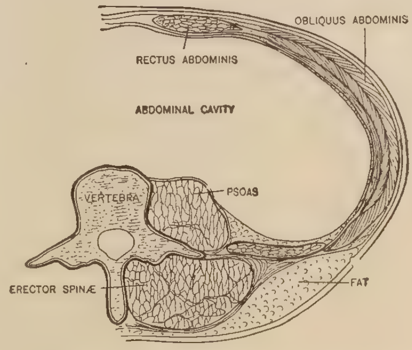


FIG. 42. A diagram of a cross-section through the lumbar region of the body. The erectors of the spine (erector spinæ) and the psoas muscles acting against each other keep the spinal column erect.

Mistakes made in trying to stand Erect. The most common of all mistakes made in trying to acquire a good carriage is to try to bring the head and neck to an erect position by forcing back the shoulders. The true remedy is to straighten out the spinal column on which the head rests.

Another common mistake made in trying to stand erect is to throw the head and chest up and allow the abdomen to be thrust forward. The trouble is that although the muscles along the back are contracted, bringing up the upper part of the spine, yet the psoas and abdominal muscles are allowed to relax, and the spinal column bends inward in the lumbar region.

A third mistake is to lift the shoulders and throw backward the entire upper part of the body when trying to bring the shoulders back. The shoulders should be drawn backward by pulling the scapulas flat down against the back, and this can be done without moving any other part of the body.

Importance of acquiring a Correct Carriage in Youth. If the body is not held erect in youth the bones will harden in a stooping position, the cartilages between the vertebræ will become wedge-shaped, and the muscles will develop in length to fit a stooped skeleton instead of a straight one. Youth is also the best time to build up and strengthen weak muscles, and to teach all the muscles to keep a proper amount of contraction.

The easiest way to acquire an upright carriage is to form the habit of sitting, standing, and walking erect. "Stand tall," and the muscles will fall into the habit of keeping the spinal column upright. It is possible, however, by suitable exercise, to develop and strengthen weak muscles, and if you are inclined to stoop you should exercise especially the mus-

cles that support the spine. A teacher who understands the science of posture is a great aid in improving the carriage of the body, for unless exercises are properly carried out they may make worse the defects they are intended to remove.

The Body balanced over the Feet in Standing and Walking. In the erect position the body must be balanced over the feet, and if one part of the body is too far forward or backward, some other part must be thrust out in the opposite direction to balance it. If the head droops forward, or if the shoulders are carried too far forward, so that the weight of the arms pulls forward instead of straight downward at the sides, the spinal column between the shoulders sinks backward in a balancing curve. If any part of the body is out of position, it will force other parts out of position also; so for good posture each part of the body from head to feet must be in place. Improper shoes and defective feet are frequent causes of bad posture. The feet should point straight forward in walking, and if the heels pound, the whole body should be swayed forward at the ankles so that the chest will be over the toes.

HYGIENE OF MUSCLES

All the cells of the body live together, and it is not possible to have some of them in bad condition and the remainder of them in good health. Whatever keeps the whole body in health, therefore, benefits the muscles. Among these things are plenty of good food, fresh air, and sleep. Other things that are necessary, not only for the health of the muscles but for the health of the whole body, are *exercise* and *rest*.

Importance of Exercise. Exercise benefits the body in many ways. It quickens the breathing and starts the heart to beating faster, and it stirs up the different organs of the

body and causes more blood to flow through them. Without exercise the muscles become weak and soft, and it is also true that if the muscles are not exercised the whole body, especially the digestive organs, will get out of order. A whole book could be written on this subject, but any one who wishes to take healthful exercise knows how to do so, and we will merely call your attention to the following important facts:

The muscles should be exercised every day. Almost every one who is lazy and neglects to do this suffers, for, generally speaking, without exercise the body cannot keep in health. *Exercise should be stopped before one becomes too tired*, for too much exercise is worse than not enough. *Whenever possible, exercise should be taken outdoors.* Outdoor games furnish enjoyment, fresh air, and exercise all at the same time and are the best of all forms of exercise.

Effect of Tobacco and Alcohol on the Muscles. Tobacco weakens the muscles. Athletes who wish to have their muscles in such condition that they will contract with the greatest possible power are not allowed to use it. Alcohol also weakens the muscles, especially in any long-continued effort. In mountain climbing in the high Alps it was found by experiment that a moderate amount of alcohol decreased the power for work 20 per cent.

Summary. The muscles number more than five hundred and make up more than two fifths of the body weight. They move the body, help inclose the body cavities, and assist in binding the skeleton together. The two classes of muscles are the voluntary and involuntary.

A muscle has a framework of connective tissue by which it is attached to the skeleton. In some cases the connective tissue forms a tendon and runs to a bone at a distance from

the muscle. The tendons are held down close to the skeleton by ligaments. The muscles of the body keep a certain amount of contraction, as is shown by the fact that a dead body will not stand up. Most of the muscles are arranged in pairs, one muscle of the pair working in opposition to the other. The nervous system controls the muscles and causes them to work together in a wonderful manner.

In the carriage of the body, the muscles of the spinal column are very important. The erectors of the spine, the abdominal muscles, and the psoas muscles support the spinal column and should be taught to keep a proper amount of contraction. The best way to do this is to form the habit of standing and walking erect.

A common mistake in trying to acquire an erect carriage is to pull the shoulders back instead of straightening up the spinal column. Another mistake is to allow the spinal column to bend forward too much in the lumbar region. A third mistake is to attempt to pull the shoulders back by raising them and throwing back the entire upper part of the body. In youth is the time to acquire a good carriage.

The body is balanced over the feet when in the upright position, and one part out of position throws other parts out of position also. Incorrect shoes and bad feet are common causes of bad posture.

Exercise is necessary, not only for the health of the muscles, but for the health of the other organs of the body as well.

QUESTIONS

How many muscles are in the body? How much of the body weight is muscle?

Give three functions of the muscles. What causes a muscle to contract? Explain how the biceps muscle bends the arm. Name

the two classes of muscles. What is the difference between them? To what are the voluntary muscles attached? Where are the involuntary muscles found?

Describe the connective tissue skeleton of a muscle. How is a muscle attached to a bone? Of what is a tendon composed? What advantage is there in having tendons in the body? How are the tendons kept close to the bones?

Why does a man's head remain erect when he is awake and fall forward when he goes to sleep? What are antagonistic muscles? Give an example. Why are the muscles of the body arranged in pairs? What effect have the antagonistic muscles on our movements?

What has the nervous system to do with our movements? By what part of the nervous system are the voluntary muscles controlled? Where are some of the muscles that are used in walking? When these muscles are used, do you think of the movements caused by them?

What part of the skeleton supports the head and trunk? What muscles keep the upper part of the spinal column erect? What follows if these muscles are weak or relaxed too much? Give two functions of the abdominal muscles; two functions of the psoas muscles. If these muscles are weak or relaxed, what effect has it on the curves of the spinal column? What is the best method of training the muscles to hold the spinal column erect? Give the rule for position in standing and walking. What mistakes are often made in trying to stand erect? Why is it important to acquire a correct carriage in youth? Why is it impossible to bend over when standing close against a wall? What effect on the spinal column has drooping the head? How should the feet be held in walking?

Name four things necessary to the health of the body. Mention some of the effects of exercise on the body. What effect has lack of exercise on the muscles? on the other organs of the body? Give three important facts relating to exercise and health. What effect have tobacco and alcohol on the muscles?

REVIEW QUESTIONS

Chapter I. Of what are living things composed? How do cells originate? Why is it necessary that there should be a division of labor among the cells of the body? Name some of the different kinds of cells in the body and give their functions.

Define: protoplasm; nucleus; tissue; organ; anatomy; physiology; hygiene.

Chapter II. Name and locate the two body cavities. What is in each? Where does man belong in the animal kingdom? Mention some ways in which the bodies of all vertebrates are alike. How does the human body differ from the bodies of all other animals?

Chapter III. What is the function of the nervous system? Explain why some such system is necessary in the body. Name the divisions of the brain. Describe a nerve. What is the function of the nerves?

Define and give the function of the following: central nervous system; sympathetic; dura mater; arachnoid; pia mater; cerebro-spinal fluid.

Chapter IV. Give three functions of the skeleton. What part of the skeleton forms a central axis to which all the other parts are joined? Name bones of different shapes, with their functions. What materials are in bones, and what is the function of each kind of material? What advantage is there in the hollow structure of bones?

Define: compact; spongy; marrow; periosteum.

Chapter V. Name two classes of joints; three kinds of movable joints. Describe cartilage and tell where it is found. How is friction kept down in the joints? What are ligaments? How is the skeleton made springy? How does the human skeleton resemble other vertebrate skeletons? How does it differ from the skeleton of an ape? Mention some points in connection with the hygiene of the human skeleton. How would you treat a broken bone? a dislocation? a sprain?

Chapter VI. Give the functions of the muscles. How are muscles attached to bones? Explain how the muscles move the body. What muscles are important in the carriage of the body? How may an erect carriage be acquired? What mistakes are made in trying to stand erect? Why should the body be carried erect in youth? Speak of the importance of exercising the muscles. What effect does any part of the body that is out of position have on other parts of the body?

CHAPTER VII

FOODS AND ENERGY

TO-DAY we take in food. To-morrow the food is gone and we are hungry still. We eat again and the next day find our need for food as great as it was at first. We spend our lives working for food and eating food, and yet only a few short hours behind, hunger is always following on our trail.

Why can we not forget all about food? What makes us want to eat? Why do we spend our money for something that we cannot keep? Why not give up eating and have time to rest and enjoy life? *Because without food the life of the cells and of the body comes to an end.*

Why the Cells need Food. The living protoplasm in the cells is continually wasting away. In certain parts of the body the cells are constantly dying[1] and being replaced by new cells. Other new cells are needed when the body grows in size (page 10). New protoplasm, therefore, is constantly being built up for the repair and growth of the cells, and this protoplasm is formed from the materials that are in the foods. *Food is necessary to furnish material for the repair and growth of the cells.*

The cells get their energy — their warmth and power to work — from the food. A muscle cell gets its strength, a

[1] It is estimated that fourteen billion red blood corpuscles die in the body every day. Great numbers of cells also die on the surface of the skin

bone cell gets its power to build bone, and all other cells, whatever they do, get their power to work from the energy which is in the food. Just as a locomotive gets its energy — its warmth and power to move — from the fuel which is burned under its boiler, so the cell gets its energy from the food which is burned within the cell. Cut off the fuel from a locomotive, and it will become cold and still. Cut off the food from a cell, and it will lose its energy and become a dead cell. *Food is necessary to furnish energy to the cells.*

THE CHEMISTRY OF FOODS

Molecules and Atoms. In the study of chemistry we learn that everything that we can see, feel, taste, or smell is composed of very small parts called *molecules*. Just as a house is built of bricks, so are wood, stone, water, earth, air, and other substances composed of molecules.

Molecules are so small that millions of them are required to build the smallest object that can be seen with the most powerful microscope. They are so small that we cannot imagine how small they are. Yet chemists study molecules, and they have discovered some very wonderful things about them. One of the most wonderful of these discoveries is that molecules are composed of still smaller particles called *atoms*. There are about eighty kinds of atoms, all differing in many ways.

Elements and Compounds. *Elements* are substances that have only *one* kind of atoms in their molecules. *Compounds* have *two or more* different kinds of atoms in their molecules. Perhaps you do not understand what you have just read, but if we play that we are building molecules, you will probably

get a clear idea of the difference between an element and a compound.

Suppose we have a pile of bricks of many different colors, — some purple, some red, some yellow, some green, some blue, and some violet. Suppose we call these bricks atoms, and of them decide to build molecules. Let us first build a molecule using only red bricks. This is like the molecule of an element, for *it has only one kind of atoms in it.* Let us now build a molecule of yellow bricks. This also is like the molecule of an element, for only one kind of atoms was used in making it. Now let us build a molecule partly of yellow and partly of red bricks. Is this like the molecule of an element? No, for it has in it two kinds of atoms. It is like the molecule of a compound. Let us now build a big molecule and put into it all the different kinds of bricks that we have. Is this big molecule an element or a compound? Read the definition of a compound again, and you will see that this is certainly a compound.

Some Common Elements and Compounds. Since there are eighty kinds of atoms, there are about eighty elements. You could tell that *iron* is an element from the diagram of its molecule, for both atoms are of the same kind. *Gold* is another element, the atoms in its molecule being the same. Other common elements are *silver*, *copper*, *lead*, *tin*, *zinc*, *sulfur*, and *carbon* (the black substance of which charcoal and soot are composed, and which you see on the burnt end of a match). Still other elements are *oxygen*, the gas which is taken into the blood from the air when we breathe; *hydrogen*, a very light gas used to fill balloons; and *nitrogen*, a gas making up about four fifths of the air.

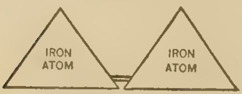


FIG. 43. A molecule of iron. Iron is an element because all the atoms in its molecule are of the same kind.

Since the eighty different kinds of elements combine in very many different ways, there are thousands of compounds all about us. Wood, stone, water, and earth are all compounds. Rocks and the ores of metals are compounds. Dynamite and gunpowder are compounds whose molecules fly to pieces with great force. Everything that you eat and wear is a compound, and if you should pick up the thing nearest your hand, you would probably find that you were holding a compound.

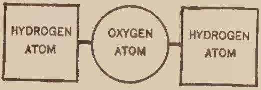


FIG. 44. A molecule of water. Water is a compound because it has more than one kind of atoms in its molecule.

Compounds Different from the Elements of which they are formed. When blue and yellow paint are stirred together, the mixture is neither blue nor yellow, but green. So a compound may be very different from any of the elements of which it is formed. Thus when carbon (a black solid) and sulfur (a yellow solid) unite, they make a liquid. When oxygen and iron unite, they make the red rust which you have so often seen. This rust is not a gas like oxygen, nor is it a tough and hard metal like iron. It is a compound, and very different from each of the elements (oxygen and iron) of which it is made.

Water is another compound which is different from either of the elements in it. Hydrogen and oxygen are both gases, but when they unite, they form water, a liquid. Carbon and oxygen also form a compound very unlike either of the elements entering into it. A piece of charcoal is a black solid which you can see and handle, and oxygen is

FIG. 45. A molecule of carbon dioxid. This gas is a compound, its molecules having in them two kinds of atoms.

the gas of the air which is so necessary to our lives. But when carbon and oxygen unite (as they do when you burn a piece of charcoal) the compound, carbon dioxid, is a poisonous gas very different from the solid carbon, and also very different from the life-supporting oxygen.

The Language of Chemists. Chemists do not write out the whole names of the elements, but write H for hydrogen, O for oxygen, S for sulfur, C for carbon, and other short signs for the other elements. They have also a short way of writing out the kinds of atoms and how many of each kind are in a compound. Thus they write H_2O (read: H two O) for water, meaning that in a molecule of water there are two atoms of hydrogen and one atom of oxygen. For carbon dioxid, the poisonous gas which we breathe out from the lungs, and which is formed when anything containing carbon is burned, they write CO_2 (read: CO two), meaning that in a molecule of this gas there are one atom of carbon and two of oxygen.

CLASSES OF FOOD

From plants and animals the people of the world obtain many different foods. All these foods, however, can be put into three great classes,—the *carbohydrates*, *fats*, and *proteins*.

Carbohydrates. The carbohydrates include the starches and sugars. Almost all of them come from plants. Nearly every plant has its own kind of starch, and we have corn starch, wheat starch, oat starch, potato starch, arrowroot starch, and many other varieties of starch. All the grains, and potatoes and most other vegetables, are starchy foods.

Sugar is an important food. Most of the sugar that we use comes from sugar cane and the sugar beet. Besides what

we purposely add to our foods to make them pleasant to the taste, we get considerable amounts of sugar in maple syrup, molasses, honey, and fruits, and there is some sugar in corn, sweet potatoes, milk, and many other foods.

Fats. There is no difference between fats and oils, except that at ordinary temperatures fats are solid and oils are liquid. For use as food they are the same, and are all called fatty foods.

Among the common fatty foods are butter, taken from milk; lard and cotton-seed oil, used in cooking; olive oil, used in salads and dressings; and the fat that is always found in meat. Besides the fats obtained from these foods we get some fats in eggs, cheese, corn, chocolate, and in a great many other foods.

Proteins. Most of the food that we get from animals contains proteins. Lean meat, fish, eggs, milk, and cheese, all contain protein matter. Wheat, corn, and other grains contain a considerable proportion of protein; but of all common foods obtained from plants, peas and beans are the richest in proteins. The table in the back of the book shows the proportion of proteins, carbohydrates, and fats in many foods.

Chemical Composition of the Different Classes of Foods. The carbohydrates contain the three elements, carbon, hydrogen, and oxygen, — and in the common carbohydrates, as in water, there are always twice as many atoms of hydrogen as there are atoms of oxygen. Thus, common sugar is $C_{12}H_{22}O_{11}$, there being two atoms of hydrogen for one of oxygen. Fats contain the same elements as the starches and sugars, but in different proportions, having in them much less oxygen than is found in the carbohydrates. Proteins contain all the elements (carbon, hydrogen, and oxygen) which are found in the other foods, and in addition they

contain nitrogen and usually very small amounts of sulfur, phosphorus, iron, and other elements.

All Foods come from Living Things. From what you have already learned you will know that the principal elements in food are very abundant in the world. Oxygen and nitrogen make up nearly all of the air. Water is two thirds hydrogen, as you could tell by counting the number and kinds of atoms in its molecules. Carbon is abundant in wood; coal is nearly all carbon; and there is much carbon in the rocks of the earth.

But you could not live on water, coal, and air. They contain all the chief elements of our food, but it is only when these elements have been built up into the proper compounds that they are useful in nourishing the body. These compounds we find only in the bodies of living things, so all our food must come from the bodies of animals or from plants. "In building our house, we can use only bricks ripped from the walls of other houses."

Uses of the Different Classes of Foods. Protoplasm is living protein matter; it is always partially composed of nitrogen, and any food which is used in cell building must contain nitrogen. The proteins are therefore *the building foods*. The fats and carbohydrates lack the necessary nitrogen, and cannot be used in cell building. They are *fuel foods, useful for burning in the cells to furnish energy*. The proteins when burned also furnish energy to the cells, but their main use is *to provide materials for building new protoplasm.*

OTHER THINGS NECESSARY TO THE BODY

Oxygen and Water. Besides the three classes of foods that we have studied, there are certain other substances which the

body must have to keep it in health. Among these things oxygen takes the first place. We breathe it in constantly, and if the supply of oxygen is cut off for even a short time, we die. Water is also absolutely necessary to the body. Besides the water that we drink, we get a great deal of water in our foods, as you can see by referring to the table of foods in the back of the book. Potatoes are more than 80 per cent water; beef is more than half water; and even in dry foods like rice and beans there is water.

Minerals. Several minerals are needed by the body. Of these salt is needed in the greatest quantity. During the time of growth the body must have also a considerable quantity of lime to build the skeleton. Iron in small amounts is necessary for the formation of the red blood corpuscles, and small amounts of several other minerals are needed by the body. Some of these minerals we get in water, and others in our food. Vegetables have a special diet value because of the large amounts of lime, potassium, and other minerals that they furnish the body.

Accessory Food Substances. Certain other substances (sometimes called "vitamins") are necessary for health or even for life. Chemists do not yet know what these substances are, but by feeding-experiments on animals and by a study of human diseases it has been determined that there are at least three of them. The lack of one of these (the "antineuritic" diet factor), which is especially abundant in the outer layer of grains, causes a disease of the nervous system called *beriberi*. Inflammation of the eyes, failure to grow, and possibly rickets are due to a lack of a second accessory substance which is soluble in fat and is found in the green parts of plants, the yolk of eggs, and in the fat of milk. The third accessory food substance (the "antiscorbutic" sub-

stance) is found especially in fresh fruits and vegetables, and scurvy is caused by a diet that is deficient in it.

Among rice-eating peoples beriberi is common, but in our country nearly every one has a sufficient supply of the anti-neuritic substance. But it seems probable that a goodly number of our people, especially growing children, have an insufficient supply of the fat soluble substance, and it has been proved that in many cases physical well-being is promoted by adding foods rich in the antiscorbutic substance to the diet.

Summary. The human body constantly requires food. This food is necessary to furnish building material and energy to the cells.

All matter is composed of molecules that are built of still smaller particles called atoms. Elements have only one kind of atoms in their molecules. Compounds have two or more kinds of atoms in their molecules. There are about eighty elements and thousands of compounds. Compounds are often very different from any of the elements of which they are formed.

The three classes of foods are the carbohydrates (starches and sugars), the fats, and the proteins. The carbohydrates are obtained chiefly from plants. They contain carbon, hydrogen, and oxygen, there being in them two atoms of hydrogen for each atom of oxygen. Fats and oils contain these same elements but in different proportions. Proteins, in addition to the elements found in the other foods, contain nitrogen. Lean meats, eggs, milk and cheese, grains, and peas and beans are the principal protein foods.

The elements found in foods are very abundant in the world, but only compounds built up by living plants and animals can be used by man for food. The proteins give energy to the body, and they are the only foods that can be

used in building protoplasm, because only the proteins contain nitrogen. The other foods furnish energy to the body.

Oxygen, water, and certain minerals are also necessary to the body. The body obtains its minerals from water and foods. Green vegetables are especially valuable for their minerals.

QUESTIONS

Give two reasons why the body needs food. Why do the cells need building material? Why do they need energy?

Of what is all matter composed? Of what are molecules composed? What is an element? What is a compound? Name some elements; some compounds. Name some compounds that are different from the elements of which they are composed. Give some examples of the short signs that chemists use.

What are the three classes of foods? What two kinds of carbohydrates are there? From what are they obtained? Mention some starchy foods; some foods that contain sugar. What is the difference between a fat and an oil? Mention some fatty foods. Mention a number of foods that are rich in proteins.

What elements are in carbohydrates? In what proportion are the hydrogen and oxygen in them? What elements are in fats? Give two uses of the proteins in the body. How are the carbohydrates and fats used in the body? From what kind of objects are our foods obtained?

Mention some other things that are needed by the body. Where does the body obtain its oxygen? water? mineral matter?

When gas or oil is burned, what becomes of the atoms of which its molecules were composed?

CHAPTER VIII

THE DIGESTIVE ORGANS

WE have now learned that the cells of our bodies must have food. But before one of the cells in the brain, for instance, can use the beefsteak or the potato that lies on your plate, many changes must be made in these foods. We therefore have a great system of organs whose business it is to work over and prepare the foods for the cells. These are the *digestive organs.* Of all parts of the body, it is the most important to understand the digestive system, for oftener than any other part of the body, these organs fail in their work, and interfere with the health.

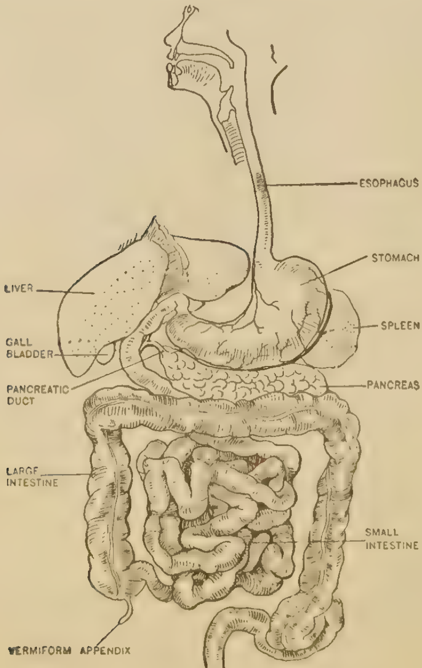


FIG. 46. The digestive organs.

The Digestive System. The digestive system includes the *alimentary canal* and

certain *accessory* or *assisting* organs of digestion, — the *teeth*, *salivary glands* (Fig. 54), *liver*, and *pancreas*. The alimentary canal is a long passageway through the body, into which the food is taken while it is being digested. The teeth grind the food into small pieces, and the other accessory organs of digestion pour juices into the alimentary canal that assist in digesting the food. Before beginning the study of the digestive organs it is well to have a general idea of the structure and function of a gland, for the whole digestive system is in the main a collection of glands.

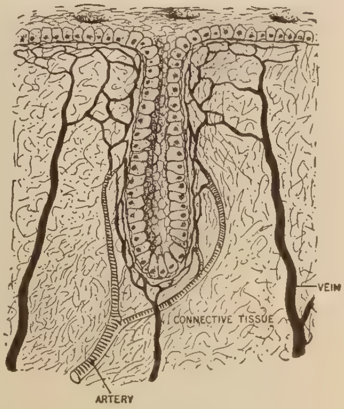


FIG. 47. A section through a simple gland.

A Simple Gland. In a simple gland the cells are arranged in the form of a hollow tube (Fig. 47). On one side the gland cells take in water and other materials from the blood. On the other side the gland cells give off a liquid into the hollow in the center of the gland. When the gland cells give off liquid[1] the liquid flows out of the mouth of the gland. The gland is then said to *secrete*, and the liquid from a gland is called the *secretion* of the gland.

[1] In some glands the cells merely take up on one side materials from the blood, and on the other side give off the same materials into the central opening of the gland. A sweat gland is an example of this class of glands. The water and the salt of the perspiration merely flow from the blood through the cells of the gland, and come out on the skin as sweat. Other glands build up new substances with the materials which they take from the blood. The glands of the

THE ALIMENTARY CANAL

The alimentary canal is almost thirty feet in length. Its principal divisions are the *mouth*, *pharynx* (throat), *esophagus*, *stomach*, and the small and large *intestine*. In its walls are muscles that contract on the food and force it onward through the canal. Beginning with the lips, the alimentary canal

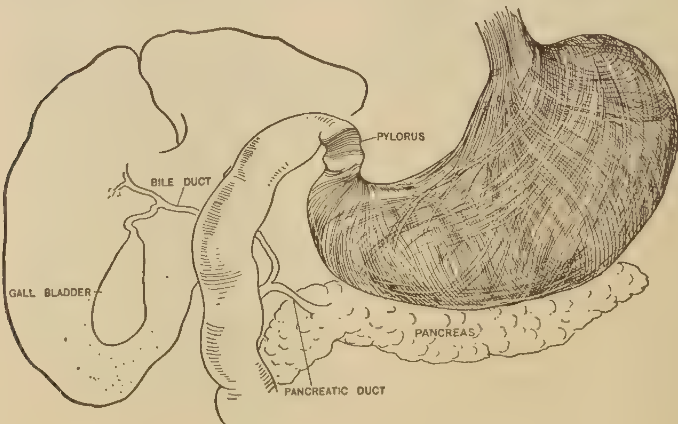


FIG. 48. The stomach, liver, and pancreas.

is lined throughout with a smooth *mucous membrane*. This differs from skin in having a pink color and in being kept moist with sticky mucus (Fig. 6), which causes the food to move easily along in its course through the alimentary canal.

The Stomach. The food is taken into the mouth, passes back through the pharynx, and goes down the esophagus.

stomach are examples of this kind of glands. The cells in these glands build up and give forth in their secretion a substance called *pepsin*, which digests the protein foods.

At the bottom of the esophagus is the stomach. This holds about three pints, and when full is about a foot long and four inches through in the thickest part. When empty, however, the stomach draws up and occupies much less space. *The function of the stomach is to serve as a storehouse for food* so that enough can be eaten at one time to supply the body for several hours, and also *to secrete gastric juice.*

The Glands of the Stomach. In the inner coat of the stomach wall are great numbers of *gastric glands*, which

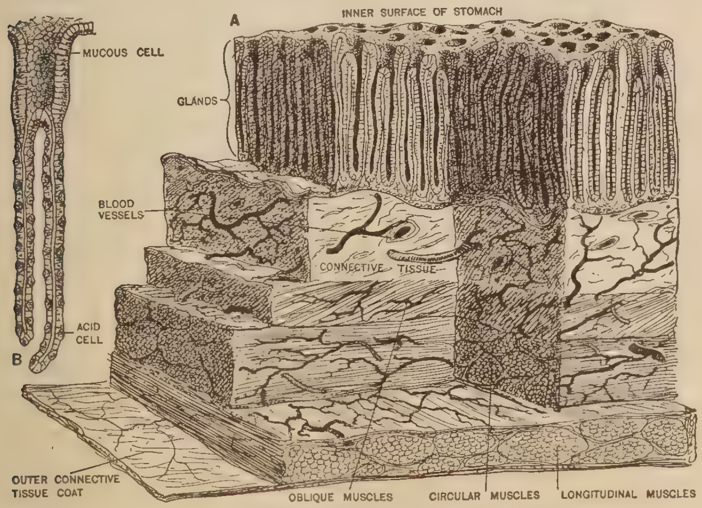


FIG. 49. A section of the wall of the stomach, showing muscles and glands. *B* is one of the glands more highly magnified.

secrete gastric juice for digesting the food and for killing bacteria. Each gland is a little circular depression (like a little well) in the wall of the stomach. If a handkerchief be spread over the hand and thrust down into the hand

with a pencil as you see in Figure 50, the shape of a simple gastric gland, and the way it lies in the stomach wall, will be very well represented. Some of the gastric glands branch in their lower parts; but they are all formed by folding the inner layer of the stomach wall into deep narrow pockets. Figure 49 shows how closely these glands are packed together, and it also shows how small they must be, for they do not reach more than halfway through the stomach wall, although the wall itself is little thicker than a piece of heavy cloth.

FIG. 50. To illustrate how a gastric gland is formed by an infolding of the stomach wall.

The Gastric Juice. From two and a half to five quarts of gastric juice are secreted in a day. Most of the gastric juice is water, but it contains *pepsin* for digesting the protein food, and *acid.* The acid kills many bacteria, thus keeping them from getting into the intestine and causing trouble there. It is useful in digestion also, since without the acid the pepsin is unable to digest the protein foods.

The Muscles of the Stomach. The entire alimentary canal from the top of the esophagus onward, has a *circular* and a *longitudinal* layer of muscles in its walls. The stomach has these two muscle layers, and has in addition a layer of *oblique* muscles. There are, therefore, circular muscles running *around* the stomach, longitudinal muscles running *lengthwise* of the stomach, and oblique muscles running *slantingly* in the stomach walls. These muscles force the food onward through the stomach; and during digestion, especially in the lower part of the stomach, the muscles keep contracting and mixing up

the food in the gastric juice. At the *pylorus*, or point where the stomach joins the small intestine, the circular muscles are thickened into a strong ring, the *pyloric muscle*, which closes the opening between the stomach and intestine while digestion is going on in the stomach. After stomach digestion has been finished, the circular muscles contract above the food, the pyloric muscle opens at the same time, and the food is forced into the intestine (page 112).

The Small Intestine. The small intestine is coiled in the abdominal cavity. It is much the longest part of the alimentary canal, having a length of nearly twenty-two feet. In its walls are *intestinal glands*, very similar to the glands of the stomach. They secrete the *intestinal juice*, which aids in digesting the food. The juices of the liver and of the pancreas are also emptied into the small intestine, and the digestion carried on here is even more important than the digestion in the stomach.[1]

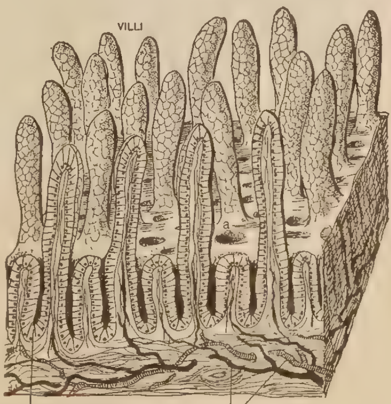


FIG. 51. Villi and intestinal glands.

The Villi. On the intestinal wall are many little finger-like projections called *villi* (singular, *villus*), which stand up in the digested food and *absorb* it, or take it into the body through the intestinal wall. So abundant are the villi that

[1] In a few cases the stomach has been removed and the esophagus connected with the small intestine. Persons on whom this operation has been performed have lived, the digestive work of the stomach being done by the small intestine.

they give the inner surface of the intestinal wall an appearance like velvet, and they absorb the food much more rapidly[1] than a smooth, even wall could do. Digestion is finished in the small intestine, and most of the liquids and the digested food are absorbed before the large intestine is reached. A little food, however, passes into the large intestine and is there absorbed while the muscles in the walls of the large intestine move onward the indigestible material.

The Large Intestine. The large intestine begins low down in the right side of the abdominal cavity, passes up the right side, then across under the diaphragm, and down the left side. Just below where the small intestine opens into it there is a small, worm-like structure (Fig. 46), the *vermiform appendix*.[2] The large intestine has no villi. Its glands secrete mucus and also throw off into the intestine some waste products from the body.

THE ACCESSORY ORGANS OF DIGESTION

The Teeth. A tooth is composed of a crown, a neck, and one or more roots. The roots stand in sockets in the jawbones, and are covered by a layer of bone-like cement. The outer coat of the crown is made of *enamel*, the hardest material in the body. Under the enamel and forming the main bulk of the tooth is the *dentine*,[3] a substance harder than the most compact bone, but not nearly so hard as

[1] The villi give from four to eight times as much absorbing surface as the smooth walls of the intestine would give.

[2] The disease called *appendicitis* is caused by germs growing in the vermiform appendix and causing inflammation. In severe cases of appendicitis, it may be necessary to open the abdominal cavity and remove the vermiform appendix.

[3] Ivory is dentine, usually obtained from the tusks of elephants, but sometimes from the tusks of the walrus or the teeth of the hippopotamus.

enamel. In the middle of the tooth is the *pulp cavity*, a little chamber containing nerves and blood vessels. Get a tooth from a dentist, or find the tooth of an animal, and break it open, and you will have no difficulty in finding the enamel, the dentine, the pulp cavity, and the little root canals through which the nerves and blood vessels come up from the jawbone into the tooth.

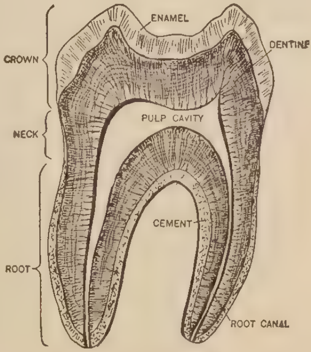


FIG. 52. Section of a tooth.

Different Kinds of Teeth and their Functions. There are four kinds of teeth,—*incisors*, *canines* or *cuspids*, *bicuspids*, and *molars*. The incisors are flat and sharp for biting off food. In the dog and other flesh-eating animals the canines are tusks which are used as weapons and in tearing flesh, but in man their principal use is to assist the incisors in biting. The bicuspids and the molars have wide surfaces for grinding the food into small pieces and mixing it thoroughly with the saliva. Examine a back tooth and notice the *cusps*, or points, on it. Observe how the cusps of the upper and lower teeth fit into each other when the jaws are tightly closed. Then notice how the jaws move sidewise in chewing, and you will readily understand how the food is crushed and ground to pieces as the teeth slide across each other.

Temporary and Permanent Teeth. The jaws in childhood are too small to hold the large teeth which we need in later life. In early life we have therefore a set of twenty small *temporary* teeth, and in later life a set of thirty-two larger *permanent* teeth. The earliest permanent teeth to appear are the first

molars, which come in behind the temporary molars about the sixth or seventh year.

Care of the Teeth. Decay of the teeth is caused by bacteria, which find a splendid place to grow in the moist, warm food between the teeth. It is also thought that bacteria are the

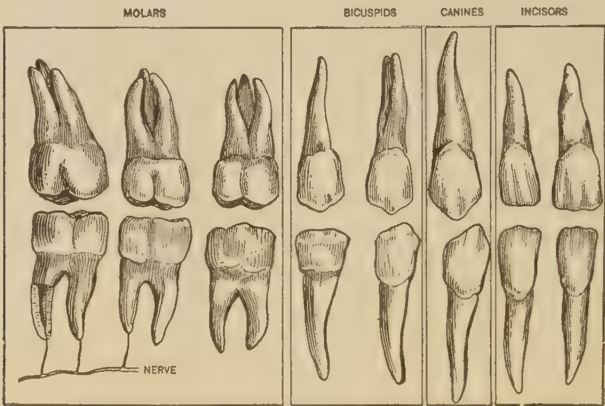


FIG. 53. One half of the permanent teeth.

cause of tartar, a dark hard substance that collects on the teeth of some persons. It is evident that the best way to preserve the teeth and to keep them white and beautiful is to keep them clean, so that bacteria will find no food materials among them. They should be brushed with pure soap or a good tooth powder after each meal, or at least in the morning and at night before going to bed. Particles of food should be removed from between the teeth with a wooden or quill toothpick, or with a piece of thread. It is very

[1] A common error is to mistake the first permanent molars for temporary teeth, and to allow them to decay, thinking that they will be replaced by new teeth. When there are three double teeth on one side of the jaw, the back one is a permanent tooth.

important not to break the enamel by biting on thread, nuts, or other hard substances; for where the enamel is broken and the dentine exposed, decay soon follows. Tartar should be removed by a dentist, for it causes the gums to shrink and expose the necks of the teeth below the enamel.

When decay has begun in a tooth, the only remedy is to have the cavity filled by a dentist. This should be done before the cavity becomes large and gets down close to the nerves in the pulp cavity of the tooth. The teeth are so valuable that we cannot afford to lose them, and it is far better to have a dentist look them over occasionally and fill all small cavities than it is to suffer later from toothache, neuralgia, and indigestion, and to pay for crowns, bridge work, or artificial teeth.

The Salivary Glands. There are six salivary glands,—three pairs. The two *sublingual* glands are under the tongue, the *submaxillary* glands are under and behind the corners of the lower jaws, and the *parotid*[1] glands are in front of the ears. The saliva is carried from the glands to the mouth through circular canals called *ducts*. The ducts of the submaxillary and of the sublingual glands of each side of the head unite before they enter the mouth. The ducts from the parotid gland open on the inside of the cheeks opposite the second molars of the upper jaw. The

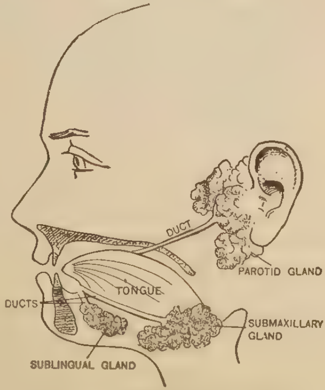


FIG. 54. The salivary glands.

[1] In mumps the parotid glands are swollen and inflamed. The other salivary glands also are occasionally affected.

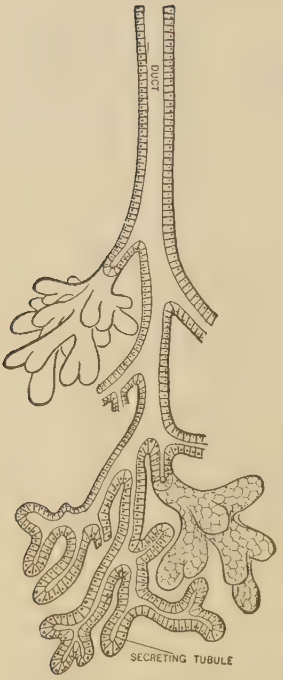


FIG. 55. Diagram of a longitudinal section of a salivary gland. A salivary gland is formed by folding in the lining of the mouth in the same way that a gastric gland is formed by folding in the lining of the stomach. The difference in the plan of the two glands is that a gastric gland branches only a few times, while a salivary gland has hundreds of branches.

saliva is secreted by the cells in the small branches of the gland (Fig. 55) and flows into the main duct and on into the mouth.

Uses of the Saliva. The saliva moistens food and makes it possible to swallow dry food like crackers, which without saliva would become dust in the mouth. The saliva is useful also because it contains a substance called *ptyalin*, which digests starch.

The Pancreas. The pancreas (Fig. 48) is a long gland, shaped something like the tongue of a dog. The Germans call the pancreas the "abdominal salivary gland," and this is a very good name for it, for it is composed of many little branches, like a great salivary gland, and the *pancreatic juice* is very much like thin, watery saliva. The pancreas is the most important of all the digestive glands, for the pancreatic juice contains *trypsin*, a substance which digests proteins, *amylopsin* for digesting starches, and *steapsin* for digesting fats. The pancreatic juice digests all three classes of foods very rapidly, and it is principally the action of this juice that makes the digestion in the small intestine so important.

The Liver. The liver is the largest gland in the body; it weighs from three and a half to four pounds. It lies in the right side of the abdominal cavity close up to the diaphragm, one lobe running down close to the body wall and another extending across under the diaphragm and covering the inner end of the stomach. The liver cells secrete *bile*, and running all through the liver is a system of little ducts that collect the bile and bring it all to one large bile duct. This large duct empties into the upper part of the small intestine.

On the under side of the liver is a little pear-shaped sac, called the *gall bladder* (Fig. 48). When digestion is not going on, the opening of the bile duct into the small intestine closes, and the bile passes into the gall bladder, where it is stored. Then when food passes into the small intestine for digestion, the mouth of the bile duct opens and the walls of the gall bladder contract, sending into the intestine a flood of greenish-yellow bile. In a later chapter we shall study about other important functions of the liver.

The Digestive System as a Whole. The alimentary canal may be compared to a long channel through the body, and the cells of the digestive organs to workers who are stationed along the sides of the canal to prepare the foods for use by pouring digestive juices over them as they pass along the canal.

In the mouth the food is ground into fine pieces and mixed with saliva, and the ptyalin in the saliva immediately starts the process of digestion. Then the journey through the long canal begins in earnest, the cells of the stomach, intestine, pancreas, and liver pouring in their juices as the food reaches their parts of the canal. On and on the food is moved, the juices digesting it and the digested portion being absorbed.

until finally only the indigestible matter of the food stuffs remains.

The digestive juices can work outside of the body as well as in the alimentary canal, and it might be possible to arrange a digestive system according to a plan differing from that which nature has used in our bodies. Yet you would have difficulty in thinking of anything simpler or better for digestion and absorption than a long tube through the body, into which the foods can be taken and soaked in digestive juices while they are slowly moved along.

The Nervous Control of the Digestive System. The digestive organs, like other parts of the body, are controlled by the nervous system. Most of the work of regulating these organs is done through the sympathetic nervous system, and it is carried on without our knowledge and without any attention from the mind. The salivary glands and the glands of the stomach, however, are controlled to a certain extent by the higher centers of the brain, and the mind has a very great effect on them. You perhaps know how, when you are hungry, the sight or odor of food will "make the mouth water." This means that at the mere thought of food the nervous system starts the salivary glands to work. The gastric glands also are influenced by the mind, as the following experiments on a dog showed:

The esophagus of a dog was divided, and when the animal was hungry, he was given some fresh beef. The dog thought he was eating a good dinner, but a tube had been connected to the esophagus in such a way that the beef did not go into the stomach but into a dish beside the dog. Nevertheless, the gastric glands promptly began to pour gastric juices into the stomach. Merely showing the food to the dog was enough to start the secretion of the glands. The experiment

showed clearly that *the mind affects the glands of the stomach* as well as the salivary glands.

At another time a tube was fitted to the part of the esophagus which was connected with the stomach, and beef was introduced into the stomach without the dog's knowing that he was being fed. In this case, the gastric juice was secreted very slowly, and the meat lay in the stomach a long time before it was digested.

These experiments show plainly that the nervous system has a great effect on the digestive organs, since the taste or smell of food, or even the sight of food, will start the secretions to flowing from some of the digestive glands. They teach us that it is very important for our food to be pleasant to the taste, in order that a good supply of juices may be secreted to digest it. They show how indigestion may be caused by eating food which is distasteful, and by eating when food is not wanted. They also explain some things which have long been known, — that a cheerful, happy life brings with it a good digestion; and that anger, quarreling, melancholy, sorrow, homesickness, and pain interfere with the digestion of the food. Our food should therefore be well cooked and served in an appetizing manner; every one should come to the table in a cheerful frame of mind, and should avoid all disagreeable topics of conversation, and all unpleasant thoughts should be laid aside until the meal is over. "Laugh and grow fat" is a wise old saying which we would do well to heed.

Alcohol and the Digestive Organs. Strong alcohol is exceedingly injurious to living cells. The stomach and the liver get in its strongest form the alcohol which is taken into the alimentary canal, and these are the digestive organs most injured by alcohol. Strong alcoholic drinks taken into the

stomach cause inflammation of the lining of the stomach. If taken often, they may cause catarrh of the stomach. They are especially harmful if taken when the stomach is empty. Alcohol taken at mealtime is diluted by the food and liquids in the stomach, and its effect on the mucous membrane of the stomach is therefore weakened. Practically all alcohol taken into the alimentary canal is absorbed through the stomach walls, and therefore the intestine is little affected by it.

After the alcohol is absorbed from the stomach it is carried to the liver. The two chief diseases of the liver, due to alcohol, are fatty degeneration, caused by beer, ale, and other malt liquors, and hardening of the liver, caused by whisky, gin, rum, brandy, and other distilled liquors. In fatty degeneration, the living protoplasm of the liver cell is replaced by fat, and finally each cell becomes a little sac of fat, unable to manufacture bile or to do the other work of a liver cell. In hardening of the liver, the connective tissue of the organ grows far too abundantly, and by contracting squeezes the delicate blood vessels and liver cells. This greatly hinders the work of the liver, and may even cause the liver cells to waste away and die. Either one of these diseases may cause death, hardening of the liver being a common cause of death among excessive drinkers.

THE DIGESTIVE ORGANS OF OTHER ANIMALS

A starfish throws its stomach out of its mouth and wraps it about the oyster or other animal that it wishes to eat. A snake has jaws fastened together with ligaments so elastic that it swallows whole animals thicker than its own body. An elephant feeds itself with its trunk, which corresponds to the nose in other animals. There are many other things

connected with the digestive systems and food habits of animals that are very different from anything that is found in man.

Teeth. Beetles, grasshoppers, and crustaceans[1] have no teeth, but have horny jaws which work sideways instead of up and down as our jaws work. Some fish have teeth, but many have none. A frog has teeth in its upper jaw, and a toad has no teeth in either jaw. All the reptiles have teeth except the turtle tribe, which, like the birds, have horny, toothless beaks. In the poisonous snakes, two of the salivary glands secrete poison, or venom, instead of saliva, and two of the teeth are long, hollow fangs through which the venom is injected into whatever the snake strikes.

The teeth of mammals differ very much according to the food which they eat. Rodents have long, chisel-like incisors for gnawing. The carnivora have long canines for killing their prey and tearing the flesh on which they feed. The herbivora have broad back teeth for grinding the grass and leaves which they eat.

Among the herbivorous animals are many interesting differences in the number and arrangement of the teeth. An elephant has ten teeth, — two upper incisors (the tusks) and eight molars. A cow has six incisors and two canines in the lower jaw, and no incisors or canines in the upper jaw. A horse has six incisors and two canines in each jaw, but the canines do not come through until about the sixth year. You can therefore tell something about the age of a horse by looking at his teeth. If he has eight front teeth in each jaw, he is over six years old. In both the cow and the horse there is a wide space between the canines and the back teeth.

[1] Hard-shelled animals with jointed legs, like the crab, crayfish, lobster, etc.

Tongues. A frog's tongue is fastened near the front of the mouth, and lies with its tip pointing backward in the mouth. So quickly that the eye cannot follow it, the frog can throw

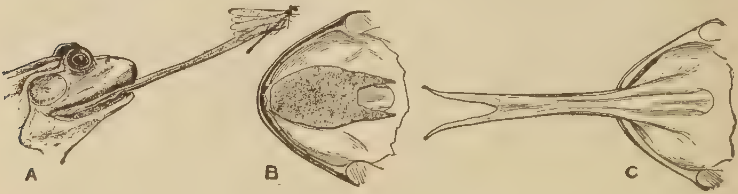


FIG. 56. A frog's tongue.

its tongue over forward and out of its mouth to catch an insect. The lizard also catches insects by shooting out the tongue. In this way some small lizards pick up from one thousand to fifteen hundred ants at one feeding. A snake uses its forked tongue for feeling, and possibly for frightening away those who might attack it; but a snake does no

FIG. 57. A chameleon catching a moth. The chameleons are closely related to the lizards. The tongue can be extended six or eight inches with lightning-like rapidity.

harm with its tongue. The tongues of carnivorous mammals are covered with sharp little points for cleaning the last particles of meat from bones. The giraffe can stretch out its tongue until it is eighteen inches long, to gather in the leaves on which it feeds.

Other Digestive Organs. Crustaceans have a *gastric mill* in the stomach. On the inside of the stomach wall there are bony plates which are rubbed together to grind up the food. A chicken (like other birds) softens its food in a *crop*, or wide place in the esophagus, and then, with small stones which it swallows, grinds the food in the *gizzard*, or thick-walled back part of the stomach.

The *ruminants*, or cud-chewing animals (cattle, sheep, goats, deer, antelope, camels, and giraffes), have the stomach

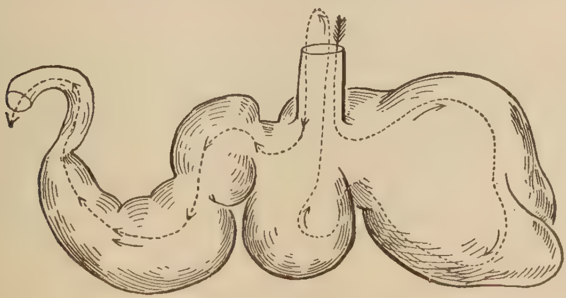


FIG. 58. The stomach of a ruminant.

in four parts or divisions. They have also two openings from the esophagus into the stomach, one a longitudinal slit in the side of the wall opening into the first division of the stomach, and the other the usual opening at the bottom of the esophagus leading into the second stomach. The food is first swallowed without much chewing, and the ball of grass or other coarse material stretches the esophagus wall, opens the slit in its side, and drops into the first division of the stomach. It is either stored here or passed on into the second division and stored there. Then, when the animal has finished eating, the food is brought up, a mouthful at a time,

and rechewed. When it is swallowed the second time it is so soft and pasty that it fails to open the slit in the esophagus wall, but passes through the upper part of the second division of the stomach into the third stomach. From there it is quickly passed into the fourth or true stomach, where it is digested.

In their wild state the cud-chewing animals are eaten by the carnivora, and this kind of stomach is an advantage to them, since they can gather their food quickly and swallow it, and then hide in a safe place while they chew it at their leisure.

In addition to the four divisions found in the stomachs of other ruminants, the camel has little sacs, formed by folding the stomach wall into pouches or pockets, in which water is stored. A muscle runs around the mouth of each sac and closes it tightly, holding the water in until it is needed. At the right time the muscle closing the sac relaxes, letting the water flow into the stomach.

The intestine of the carnivorous animals is short, and that of the herbivorous animals long, the ox having an intestine about one hundred and fifty feet in length. Judging from the human teeth and other digestive organs, man seems to be midway between the herbivorous and carnivorous animals. We may therefore conclude that nature intends that man should eat both vegetable and animal food.

Summary. Before the foods can be used by the cells they must be digested. This work is done by the organs of the digestive system, which is composed of the alimentary canal and the accessory organs of digestion. In the main the digestive organs are glands that take material from the blood and manufacture digestive juices.

The alimentary canal is nearly thirty feet in length. It

has muscles in its walls that move the food onward, and is lined with mucous membrane. The stomach holds about three pints. It serves as a storehouse for food, and the glands in its wall secrete the gastric juice. The gastric juice contains pepsin for digesting protein foods, and acid which assists in digestion and kills bacteria. The small intestine is about twenty-two feet in length. Its glands secrete the intestinal juice, and the villi on its walls absorb the digested food. The glands of the large intestine secrete mucus and throw off wastes from the body.

The body of a tooth is composed of dentine. Its crown is covered with hard enamel and it has a pulp cavity in its center. The four kinds of teeth are incisors, canines, bicuspids, and molars. There are twenty teeth in the temporary set and thirty-two in the permanent set. Decay of the teeth is caused by bacteria that grow in the food material that clings to the teeth. To prevent decay, keep the teeth clean.

There are three pairs of salivary glands, — the sublingual, submaxillary, and parotid. They secrete saliva which moistens the food and contains ptyalin for digesting starch. The pancreas pours pancreatic juice into the small intestine. This juice contains trypsin for digesting protein, amylopsin for digesting starch, and steapsin for digesting fat. The liver secretes bile, which is stored in the gall bladder until needed in the small intestine.

The alimentary canal is a long channel through the body into which the food is taken and moved along, while digestive juices are poured over it. As the food moves along it is digested and absorbed. The salivary glands and the stomach are greatly influenced by the mind, and a contented, happy life greatly aids in keeping the digestive organs in good condition.

Alcohol causes inflammation of the stomach and fatty degeneration and hardening of the liver. It is exceedingly injurious to the digestive organs and should not be taken into the alimentary canal.

The digestive organs of some other animals are very different from our own.

QUESTIONS

Why do we need a digestive system? What does the digestive system include? Name the accessory organs of digestion. Describe the alimentary canal. What is the function of the teeth? of the other accessory organs of digestion? Of what in the main is the digestive system composed?

How are the cells arranged in a simple gland? What do these cells do? What is meant by the word *secrete? secretion?*

How long is the alimentary canal? Name its chief divisions. How is the food moved through it? With what is it lined? How does this differ from skin?

Locate the stomach (page 17). Trace the course of the food into the stomach. How much will the stomach hold? Give its dimensions when full. What two functions has the stomach?

What is the function of the gastric glands? Show how a gland is formed in the wall of the stomach. How much gastric juice is secreted in a day? What does it contain? What is the use of the pepsin? Give two uses of the acid. Describe the muscles of the stomach. What two functions have these muscles? What and where is the pyloric muscle and what is its function?

How long is the small intestine? What do its glands secrete? What juices are emptied into it? Describe the villi. What is their function? What and where is the vermiform appendix? What is the function of the glands of the large intestine?

Name the parts of a tooth. What is the enamel? dentine? the pulp cavity? What is in the pulp cavity? Name the four kinds of

teeth. Give the function of each kind. How many teeth in the temporary set? in the permanent set? What causes decay of the teeth? How can decay be prevented? After decay has started, what should be done?

Name the salivary glands. What is their function? What two uses has saliva? Locate the pancreas (page 17). What does it secrete? What three substances are in the pancreatic juice? What does each digest? Locate the liver. How large is it? What does it secrete? Where is the gall bladder and what is its function?

To what may the digestive system as a whole be compared? What happens to food as it is moved through the alimentary canal?

What proof is there that the mind affects the secretion of the salivary glands? In the case of the dog, what effect on the gastric glands had the idea that he was eating? What happened when the dog was fed without knowing it? What do these experiments show? Name some of the conditions of the mind that may interfere with digestion.

What effect has alcohol on the stomach? on the liver?

How does a starfish get its food into its stomach? What is peculiar about the way a snake eats? about the way an elephant eats? Tell something about the teeth of different animals.

What is peculiar about the tongue of a frog? Tell something about the tongues of other animals.

What is peculiar about the treatment of the food in the stomach of a crustacean? of a bird? Describe the stomach of a ruminant and the course of the food through it. Of what advantage is this kind of stomach to a ruminant? Describe the stomach of a camel.

If the small intestine had a smooth wall, how long would it need to be to have the same absorbing surface that it now has (see footnote, page 94)? Explain how folding the wall of the alimentary canal into deep glands greatly increases the secreting surface.

CHAPTER IX

DIGESTION, ABSORPTION, AND OXIDATION OF FOODS[1]

Why Food must be digested. When food has been taken into the alimentary canal, it has not yet really entered the body, but is only in a passageway which leads through the body. To get into the body, it must first pass through the lining of the alimentary canal into the blood. Many of our foods must have changes made in them before they can do this, and the following experiments will show one of the changes which is necessary in many foods:

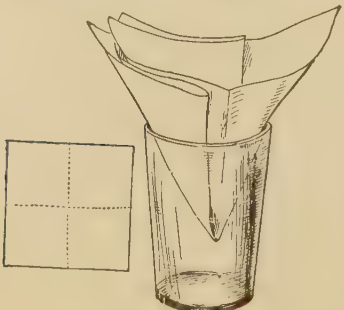


FIG. 59.

Drop a few grains of salt into a glass of water and stir it up. Does the salt dissolve? Taste the water. Are there salt molecules in all parts of the water?

Stir some clean sand into another glass of water. Does the sand dissolve? Do its molecules separate and go out through the water as do the salt molecules, or do they remain together?

Fold a piece of soft paper in the manner indicated in Figure 59. Open it at the free corners and set it in the mouth of a glass. Pour the salt water into the paper. Does

[1] TO THE TEACHER: The whole subject of the nutrition of the human body is far from elementary, and it takes careful teaching to give beginning classes any comprehension of it. It is the central idea in physiology, however, and under-

the water pass through the paper? Does the salt pass through the paper? Arrange another piece of paper the same way and pour into it the water containing sand. Does the sand pass through the paper?

When a substance dissolves in a liquid, its molecules separate. When it does not dissolve, they remain clinging together in a great mass. The single molecules of salt in the water readily pass through the paper; but the grains of sand, with their molecules all in great clusters, are caught by the paper and are not allowed to pass through.

Most of our solid foods are substances that do not dissolve in water or in the juices of the alimentary canal. Meat, butter, eggs, or bread would lie indefinitely in the alimentary canal without dissolving if their molecules were not changed. They must, therefore, be *digested*, or changed to substances that will dissolve in the stomach and intestine. *Digestion is the process of changing foods into substances that will dissolve and pass through the walls of the alimentary canal into the blood.*

You will see at once the tremendous importance of digestion, for if it is not properly performed, the food which should nourish the body may simply pass through the alimentary canal and never get to the cells which it should feed.

Changes in the Food during Digestion. The molecules of food are large, as molecules go, a starch molecule having in it four hundred and fifty atoms, while some of the great protein molecules are composed of more than two thousand atoms. *During digestion these large molecules are split into smaller molecules.* Each molecule of starch is split into ten molecules of *malt sugar*, and then each molecule of malt sugar is split

lies practically all hygiene. Additional material on this subject is given in the Appendix, and where sufficient time is given to the subject, this material should be used.

into two molecules of *grape sugar*. Thus in digestion, starch, which does not dissolve in water, has each of its great molecules split up into twenty molecules of grape sugar, which dissolve and pass through the intestinal wall. The great protein molecules and the molecules of fat are also split in digestion into smaller molecules which can be absorbed.

How the Molecules are split. In the digestive juices are very peculiar substances called *enzymes* or *ferments*, — the ptyalin, pepsin, trypsin, amylopsin, and steapsin that have already been mentioned. These enzymes have the power of splitting up[1] the food molecules. Each enzyme can split the molecules of only one class of food, so there must be different kinds of enzymes for digesting the carbohydrates, the proteins, and the fats.

Digestion in the Mouth. When food is taken into the mouth, the salivary glands begin to work more rapidly, and the ptyalin in the saliva at once attacks the starch and begins to change it to malt sugar. At the best there is not much time for digestion in the mouth, and by eating slowly we not only give the ptyalin more time to work on the starch, but we also give the glands more time to secrete the ptyalin, and we mix the ptyalin more thoroughly with the food. All this increases starch digestion in the mouth.

Digestion in the Stomach. The food remains in the stomach from one to four hours. The main digestion carried on here is that of the proteins by the pepsin of the gastric juice. This enzyme splits the protein molecules into smaller molecules called *peptones*, which dissolve in the gastric

[1] Enzymes are found only in living animals and plants, but they can work outside of a living body as well as in it. If ptyalin is put into a dish with starch, or pepsin with a protein, digestion will go on in the dish as it does in the alimentary canal.

juice. The stomach keeps working the food along, and especially in its lower part keeps mixing the gastric juice with it. After about an hour the pylorus opens and lets the more liquid part of the food pass on into the intestine. The pepsin continues its work on the food remaining in the stomach, and as this is sufficiently digested, it is passed on from time to time into the intestine. The acid in the gastric juice stops the action of the ptyalin on the starch, but in the upper part of the stomach the acid sometimes takes an hour or more to work through the food. Much starch is, therefore, digested by the ptyalin after the food leaves the mouth.

Digestion in the Small Intestine. When the food passes into the small intestine, the glands of the intestine secrete their juices, the gall bladder contracts and sends the stored-up bile into the intestine, and the pancreas begins to send in the pancreatic juice with its three powerful enzymes, — trypsin, amylopsin, and steapsin. Then the following enzymes finish the digestion of the foods:

Amylopsin changes the starches which escape the ptyalin into malt sugar. Then each molecule of malt sugar, and also the cane sugar (ordinary sugar) that we take in our food, is split by enzymes in the intestinal juice[1] into grape sugar. Thus all the starches and sugar are finally changed by digestion into grape sugar.

Trypsin digests the proteins which have escaped the pepsin.

Steapsin digests the fats. Bile is not a digestive juice, for it contains no enzymes; but it assists in destroying the acids[2]

[1] The enzyme that digests malt sugar is called *maltase*. The enzyme that digests cane sugar is called *invertase*.

[2] The intestinal and pancreatic enzymes, like the ptyalin, cannot work when strong acids are present. Both the bile and the pancreatic juice contain minerals that unite with and destroy the acid of the gastric juice.

of the gastric juice, it in some way assists the steapsin in the digestion of the fats, and it greatly hastens the absorption of the fats.

Absorption. The liquids and the digested foods in the alimentary canal pass through the wall of the canal into the blood. This process is called *absorption* and takes place chiefly from the small intestine. After absorption the blood carries the foods all through the body, and each cell takes from the blood the food that it needs.

The Foods within the Cells. A part of the protein food taken into a cell is used for building purposes. The remainder of the food is *oxidized* (burned) within the cell. In this process, *the food molecules are torn down and the atoms that were in these molecules unite with atoms of oxygen* — the food molecules are destroyed and new kinds of molecules are formed. Therefore, in the oxidation (burning) of the foods within the cells, *the foods are destroyed and new substances are formed.* These substances are the *body wastes.* You must get clearly in mind that the same materials (atoms) that go into the cells in the form of foods come out of the cells as wastes, — *that the foods are changed to wastes within the cells.*

The Body Wastes. When sugar and fat are burned in the body, the waste products are carbon dioxid and water. When protein foods are burned or when the protoplasm of the cells breaks down, carbon dioxid and water are given off, and in addition *uric acid* and many other waste products are formed. The carbon dioxid and the protein wastes are poisonous and pass out of the body through the lungs and kidneys.

What a Cell gains by burning Food. If the foods simply go into a cell and then come out again as wastes, what does a cell gain by taking in and burning food? *A cell gains energy by the oxidation of the foods.*

When on a cold day you put coal into the stove, you do not care anything about whether or not there is coal in the stove. What you are interested in is the heat that you will get when the coal burns. So when a cell burns food, it is not profited by the atoms and molecules of the food, but by the energy — the heat and strength and power to work — that is given to the cell by the burning. In this connection it would be well to read again pages 78 and 79.

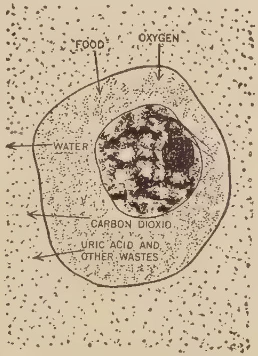


FIG. 60. The foods pass into a cell and are changed to wastes within the cell.

The Storage of Foods in the Body. Our cells must have a constant supply of food, and it is necessary to have a store of food in the body that can be used in times of sickness or starvation. When sugar is abundant, a few ounces of it can be stored by the liver until it is needed by the cells. The great store of food in the body, however, is in the form of fat. The fat is deposited about the intestines, kidneys, and other internal organs, it is packed among the muscles and in other tissues, and a layer of fat is laid down under the skin. The fat under the skin is useful not only for feeding the body in times of food scarcity, but to retain the body heat.

Fat in Animals. Animals that hibernate go into their winter quarters fat in the autumn, use up their fat during their winter's sleep, and come out thin in the spring. The camel has a store of fat in the hump on its back, which enables it to go for many days without food. Seals, whales, and other warm-blooded animals that live in cold waters have a thick layer of fat under the skin to keep in the body heat. In a whale this layer of blubber is sometimes two feet thick.

ALCOHOL AND DIGESTION

Alcoholic Drinks and Digestion. Alcohol taken with food causes an increase in the amount of saliva and gastric juice secreted, but it seriously interferes with the work of the pepsin if more than five per cent of the contents of the stomach is alcohol. Alcohol also checks stomach digestion by paralyzing the muscles of the stomach, and beer and wine contain acids and other substances that very greatly hinder the work of the ptyalin. On the whole, the rate of protein digestion is not much changed by alcoholic drinks in small quantities, but the digestion of the starch is greatly hindered. The whole question of the effects of alcohol on the *process* of digestion is of little practical importance, however, for alcohol so frequently causes diseases of the digestive organs that it would be unwise to take it into the alimentary canal, even though it greatly aided digestion.

Effects of Alcohol on the Work of the Liver. The liver manufactures bile and stores up sugar. It has besides a third function, one connected with the uric acid and other protein wastes of the body. The uric acid is poisonous to the body, and if it is not removed from the blood, rheumatism, gout, and other serious troubles follow. *The liver changes a considerable part of the uric acid to urea*, which is taken out of the body by the kidneys.

Alcohol not only produces the diseased condition of the liver so commonly found in alcohol users (page 102), but it sometimes interferes especially with the manufacture of urea in the liver. In some persons alcohol even in very small amounts (the amount that one would get in a glass of beer) seriously hinders the liver in its work of changing uric acid to

urea. A large part of the uric acid is then left in the blood to bring about its evil consequences.

Summary. Foods are digested, or split by enzymes, to make them dissolve and pass through the walls of the alimentary canal.

Starch is split into malt sugar by ptyalin in the mouth and stomach and by amylopsin in the intestine. The malt sugar and the sugar that we eat are split in the intestine into grape sugar. This grape sugar is then absorbed and carried to the liver, where it is stored until it is needed by the cells. Within the cells the grape sugar is burned, and water and carbon dioxid come out of the cells as wastes. The cells obtain energy from the sugar.

Proteins are split into peptones by pepsin in the stomach and by trypsin in the intestine. They furnish energy and building material to the cells, and are broken up into water, carbon dioxid, and uric acid, and into a number of other substances which contain the nitrogen of the protein molecule.

Fats are digested in the small intestine. They are burned to carbon dioxid and water in the cells, to which they give energy.

After digestion the foods are absorbed and carried by the blood to the cells. Within a cell, part of the protein food is used in building new protoplasm and the remainder of the food is oxidized. In this process the food molecules are torn down and new substances (the body wastes) are formed from the atoms of these molecules. By the oxidation of foods a cell gains energy.

Cells must have a constant supply of food, and there is in the body a great store of fat for use in times of sickness or when food cannot be obtained.

Alcoholic drinks increase secretion but hinder the action of

the enzymes, and on the whole make the process of digestion slower. They also produce serious results by keeping the liver from changing uric acid to urea.

QUESTIONS

Why must foods be digested? What is digestion? What kind of changes do the food molecules undergo during digestion? What is an enzyme? Name some of the digestive enzymes.

What enzyme is in the saliva and what kind of food is digested in the mouth? To what is this food changed? Give three reasons for eating slowly. What enzyme is in the stomach? What kind of foods are digested in the stomach? To what are they changed? How long does food remain in the stomach? What do the stomach muscles do during this time? What effect has the acid of the stomach on the ptyalin?

What digestive juices work on the foods in the small intestine? Name the three enzymes in the pancreatic juice. What does the amylopsin do? To what are all the starches and sugars finally changed in digestion? What does the trypsin do? the steapsin? What is the function of the bile?

What is absorption? Where are the foods taken after absorption? In what way does a cell use part of the protein food? What is done with the remainder of the food? What is oxidation? What happens to the food molecules during oxidation? What becomes of the atoms that were in the food molecules?

What wastes are formed when sugar and fat are burned within the cell? when proteins are burned in the cell? Which of these wastes are poisonous? How do they leave the body? What does a cell gain by burning food?

Why is it necessary to have food stored in the body? Where is sugar stored? In what form is the chief store of food in the body? Where in the body is the fat deposited? How is fat used by animals that sleep through the winter? Where does the camel have a store

of fat and why does it need this fat? Why do animals that live in cold climates need a layer of fat on the body?

What effect has alcohol on the secretion of saliva and gastric juice? on the rate of digestion of proteins? of starch? Why is it unwise to take alcohol into the alimentary canal? What are the three functions of the liver? What effect has alcohol on one of these functions? What diseases are caused by this?

If a cell had fats and carbohydrates, could it live without proteins? Why? If it had proteins and fats, do you think it could live without carbohydrates, or if it had proteins and carbohydrates, could it live without fats? Give a reason for your answer.

A man had trouble in digesting fatty food. What enzyme was weak in his digestive juices?

Malt contains an enzyme that does the same work as ptyalin and amylopsin. A man who had stomach indigestion took malt to relieve the difficulty. What mistake did he make? What enzyme should he have taken?

Suppose there is trouble in digesting starch. What other food can be eaten that will give the cells grape sugar?

What enzyme is lacking when there is trouble in digesting sugar, or sweet materials like candy and cake that contain much sugar? Would the use of malt or pepsin relieve the trouble? Is it possible to furnish the cells with grape sugar without eating sugar? How?

What enzymes are mainly employed in digesting the following foods: potatoes; maple syrup; butter; cheese; beans; lean meat; fat meat?

Find out what enzymes you can buy in a drug store. Do any animals have enzymes that we do not have? Do plants have enzymes?

CHAPTER X

DIETETICS

A food may be defined as a substance that can be digested;[1] *that can furnish the cells with either building material or energy, or with both building material and energy; and that does not injure the cells.* Coal contains energy, and dynamite contains great quantities of energy; but the digestive enzymes cannot split the molecules of coal and dynamite, so these substances are of no use for food. Opium can be burned in the cells, and of course must furnish heat to the cells. Yet opium is not a food but a poison, because the injury done by it to the cells is many times greater than the good done by the little energy which it yields. A true food not only must furnish energy, but also must not injure the cells.

In dietetics we have, therefore, two problems. For our food we must choose substances *that can be digested without injury to the digestive organs*, and substances *that will supply the needs of the body without injuring it.*

THE CARE OF THE DIGESTIVE ORGANS

Most digestive troubles are related to infections of the tonsils, teeth, or other parts of the digestive system; to derangement of the nervous control of the digestive organs; or to the putrefaction or fermentation of food in the alimentary

[1] A few foods, *e.g.* grape sugar, and some of the ingredients of soups, are in such a form when eaten that they can be absorbed without digestion. These, of course, need no digestion.

canal. Much of the hygiene of these organs is, therefore, connected with the treatment of other parts of the body, and less of it than was formerly supposed relates to eating habits and the selection and preparation of food.

Infections with Pus-forming Bacteria. In many persons the gums, teeth, or the bones of the jaw about the roots of the teeth are infected with pus-forming bacteria. The tonsils also are infected with these bacteria in an amazing number of persons. In many of these cases the stomach and intestine are deranged by the pus and germs that are constantly swallowed, and by the toxins that are absorbed into the blood, and relief from the digestive troubles can come only from the removal of the infection in the mouth and throat. Chronic infections of the appendix and gall bladder are also often responsible for the failure of the digestive organs to function as they should.

Defective Nervous Control of the Digestive Organs. If the nervous system is deranged, the digestive organs that are under its control often fail to function properly. Living at a high tension, lack of sleep, fatigue, worry, anger, sorrow, eye-strain, a chronic infection in some part of the body, or anything else that upsets the nervous system may therefore cause trouble with the digestion of the foods. When digestive ailments are due to the general condition of the nervous system, the remedy of course lies in the restoration of the nervous system to a proper working condition.

On the other hand, a deranged condition in the digestive organs may cause nervous troubles or intensify them. Hard or coarse food like raw vegetables or unripe fruits may so irritate the nerves of the stomach and intestine as to cause convulsions or even death in a young child, and one prominent investigator believes that, in certain persons with hyper-

sensitive nervous systems, the retained intestinal wastes produce their evil effects by over-stimulation of the intestinal nerves, — that the bulky solid masses so irritate the nerve endings that they cause the entire nervous control of the digestive system to be upset and that in this way they produce the headaches and other symptoms that often accompany a constipated condition.

Putrefaction and Fermentation of the Food in the Alimentary Canal. If there is a lack of acid in the gastric juice, bacteria may grow in the stomach and upper intestine and cause trouble by fermenting the carbohydrates and fats. Putrefaction of the proteins is an even more common cause of trouble, if the wastes are not moved along the intestine and promptly eliminated from the body.[1]

The possibility that in some cases the chief evil resulting from the retention of the intestinal wastes is the irritation of the nervous system has been referred to above, and some physicians advise against large quantities of coarse foods for certain persons with very sensitive nervous systems.

[1] The importance to the health of the prompt movement of the food along the alimentary canal cannot be too strongly emphasized. It has generally been taught that if the intestinal muscles are slow in their work, the bacteria that are always present in the alimentary canal will produce offensive gases that will be carried to the lungs and given off in the breath, and that substances that will poison the whole body will be absorbed from the intestine.

Coarse vegetables, fruits (especially if the skins are eaten), corn meal, oatmeal, and whole wheat bread furnish considerable amounts of indigestible matter which stimulate the muscles in the walls of the alimentary canal and cause them to move the food along. Drinking plenty of water softens the intestinal contents and makes it easier for them to move onward, and exercise is beneficial to most persons whose intestinal muscles are less active than they should be. Most important of all, however, is regularity in emptying the bowel. If this is done at a certain time each day, the nerves and muscles of the intestine fall into a rhythmic activity that insures a regular removal of the body wastes.

Keeping the Digestive Organs in Health. The following rules may be helpful in keeping the digestive organs in health:

1. *Eat slowly and chew the food well.* This helps in giving the nervous system an opportunity to settle down and control the digestive organs as it should. It is, of course, only one phase of a quiet, orderly life as contrasted with a life of worry and strain.

2. *Eat a reasonable amount at each meal.* The body must have a certain amount of food, and if only a little is eaten at one meal too much is likely to be eaten at another. Breakfast is the meal that is most likely to be too scant.

3. *Eat different kinds of food at each meal.* If only one kind of food is eaten, all the work is thrown on one enzyme. Too much fat may give the steapsin more work that it can do, while the amylopsin is entirely idle because no starchy food was eaten. Eating a great amount of candy at one time gives the sugar-digesting enzyme more sugar than can be digested for hours, while the other enzymes have nothing to do. This has exactly the same effect as eating too much, for in either case digestion will be long delayed. School children often injure their digestive organs by eating such foods as candy, pickles, and pastry. Some of these foods are injurious because they are taken in too great quantities, and some are indigestible and injurious in any quantity.

4. *Eat only at meal time.* After digestion, the glands of the alimentary canal should have time to rest and prepare a supply of enzymes for the next meal. Eating between meals also dulls the appetite at mealtime, and we have already seen (page 100) how hunger and a good appetite assist in causing an abundant flow of digestive juices.

5. *Drink plenty of water both at mealtime and between*

meals. Water, either hot or cold, stimulates the secretion of the gastric juice and hastens the digestion of the food. It softens the intestinal contents and helps in their onward movement. At least 4 pints of water a day are considered advisable for an adult.

6. *Do not talk about unpleasant things at mealtime.* This interferes with the secretion of the digestive juices (page 101).

7. *Exercise regularly.* Any one who does not exercise is almost certain to suffer from indigestion (page 74).

8. *Do not overwork or overstudy.* Either overwork or overstudy will bring on indigestion. Probably the nervous system is first injured, and the trouble with the digestive organs comes from a lack of proper nervous control.

9. *Give the eyes proper care.* Many cases of headache and stomach trouble are cured at once by fitting the eyes with proper spectacles or eyeglasses. Probably bad eyesight, like overwork, injures the nervous system, and the nervous system then fails properly to regulate the digestive organs. Fitting the eyes with glasses is of course far more important for those who do close work than for those whose work puts no strain on the eyes.

10. *See that the intestinal wastes are promptly removed from the body* (page 122).

AMOUNTS AND KINDS OF FOOD NEEDED

An adequate diet must supply the energy needs of the body; it must furnish the protein needed for building materials; it must contain the minerals and vitamins necessary to the cells; and it should have sufficient bulk to cause the wastes to be moved promptly along the intestine. It is very easy to select a diet that will be lacking in some of these

particulars. Therefore, a study of foods and diets usually yields great returns in health. The protein supply is one of the important elements in the diet, and we shall first discuss certain important dietetic facts relating to the proteins of the food.

Proteins of Different Value for Building Purposes. When proteins are digested, they are broken into *proteoses* and *peptones*, and before they are absorbed the peptones are split into still smaller molecules called *amino-acids*, many different kinds of which are known. Different proteins yield these acids in different proportions when they are broken up, and some proteins yield only certain ones of them. It is now known that we need for the nourishment of our bodies not a certain amount of protein, but certain amounts of these different amino-acids. It has long been known that gelatin alone will not nourish the body, and recent experiments have shown that other proteins differ in their power to supply the needs of the cells.

In these experiments, rats were fed with a suitable mixture of minerals, carbohydrates, fats, and some single protein. It was found that a certain protein (zein), which was obtained from corn and which lacks certain amino-acids, would not support life. Other proteins (gliadin and hordein), which were obtained from wheat, rye, and barley, kept young rats alive but did not enable them to grow. The proteins from peas and beans when fed alone supported life, but were also inadequate for growth. Other proteins (casein from milk, glutenin from wheat, lactalbumin from milk, vitellin from the yolk of eggs) proved adequate for both the maintenance and growth of animals.

These experiments clearly indicate that for building purposes some proteins are more valuable than others. The

proteins of meat, milk, and eggs are of good quality; speaking generally, the proteins of grains, peanuts, and soy beans are worth, for building purposes, about half as much as those of meat and milk; and the proteins of peas and beans are about half as valuable as those of grains.

Amount of Protein needed by the Body. From what has been said above, it will be evident that it is impossible to say that any definite amount of protein is required by the body unless the kind of protein is specified. But where a mixed diet is taken, so that the proteins come from various sources, men have usually eaten daily about 4 ounces of dry protein, or enough to yield about 460 Calories[1] of heat.

But notwithstanding all the feeding experiments that have been carried on with men and lower animals, and in spite of all the mass of human experience with different diets, food authorities still disagree as to the amount of protein that the diet should contain. From the results of recent studies, one investigator concludes that pellagra is due to a lack of the high-quality proteins furnished by meat, eggs, and milk. It has been announced also, as the result of investigations on animals, that the "war edema" common in European countries where there was a shortage of food is due to a lack of protein and not to a lack of vitamins or other elements in the diet; and it has been found difficult to increase the weight of persons emaciated from starvation without liberal protein feeding.

[1] A Calorie is the amount of heat required to raise the temperature of one liter of water 1° C. Not all the energy of the foods is used in warming the body, part of it being used in building protoplasm, enzymes, and other substances, and part of it by the muscles doing work. But the easiest way of measuring the amount of energy in food is to try how much heat it will give off when it is burned. The amount of energy in food, therefore, is always given in Calories, or the amount of heat which it yields when burned.

On the other hand, many authorities on foods believe that a sufficient amount of protein is provided in any normal diet and that a high-protein diet causes putrefaction in the intestine, overloads the system with protein wastes, and is a cause of disease of the kidneys and other parts.[1] Persons taking a diet high in protein are usually heavy eaters of meat, and from the present state of our knowledge it would seem wise to eat only moderately of this food and to take daily not more than enough protein to yield from 350 to 400 Calories of heat (page 353).

Amount of Energy needed by the Body. The body not only requires building material, but it must have energy. This is secured by the oxidation of the food within the cells. A man doing moderately heavy work needs food enough to furnish about 3000 Calories. Women need somewhat less than men, a twelve-year-old child as much as an adult, and young people from fourteen to eighteen more than at any other time in life.

Only the proteins supply building materials, but all the different classes of foods yield energy to the body. After the building wants of the body are supplied, it is better to use, for energy, carbohydrates and fats rather than protein, as these foods are cheaper and leave no wastes except water and carbon dioxid. After the building wants are supplied, there are no exact proportions in which protein, carbohydrate, and fat must be used, but a reasonable amount of each is advisable. A fairly liberal supply of fat seems to

[1] One investigator divided rabbits into two lots and fed them the same, except that one lot had additional protein in the form of milk casein. Those on the high-protein diet developed kidney disease, while the others remained free from it. When the experiment was repeated and the additional protein given in the form of soy beans, the results were the same.

be conducive to health, and those who have had experience in feeding consumptives believe it raises the resistance of the body to germs. A given amount of fat will yield more than twice as much energy as the same amount of protein or carbohydrate.

Minerals in the Diet. Minerals are required in the body only in small amounts, but these small amounts are as necessary for health as a proper supply of protein or other foods. Among the minerals most frequently lacking in our foods are calcium, phosphorus, and iron.[1] In general, these minerals are found in vegetables, fruits, eggs, milk,[2] and the outer layer of grains. They are lacking in meat, and persons who live chiefly on meat and white bread are especially likely to suffer because of a lack of minerals. Boiling vegetables in water removes much of the mineral matter from them, and vegetable soups are valuable for the minerals they contain. Baking potatoes and other vegetables retains the minerals in them, and this method of cooking should be more commonly employed.

The whole question of minerals in the diet is an important one, for recent studies indicate that many persons fail to get sufficient mineral matter in their food, and according to one estimate one half the people in the United States are suffering from calcium starvation. In limestone regions this min-

[1] There is much evidence to indicate that goiter, which is common in some regions and rare or unknown in others, is due to a lack of iodine in the food and water. It has been reported from Switzerland that this disease can be prevented in goitrous regions by using salt from regions where the disease does not occur, and experiments made by the United States Public Health Service in Akron, Ohio, seem to prove that goiter can be kept from developing in school children by giving small weekly doses of iodine.

[2] Milk contains only small quantities of iron, and babies that are kept on an exclusive milk diet too long lack this important mineral.

eral is supplied by the water, but in other regions a liberal supply of leaf vegetables and milk is needed to make sure that a sufficient amount of it will be secured. Milk is particularly rich in calcium, and children who are deprived of milk are almost sure to lack this element.

Vitamins. The existence of vitamins has only recently been discovered, and our knowledge of them and of their distribution in the various foodstuffs is as yet far from complete. Nearly all of us get an ample supply of the antineuritic vitamin, but it is advisable to plan the diet so that a fair supply of the others will be insured. This can be done by including fresh fruits, fresh vegetables (especially leaf vegetables), and fresh milk in the diet. More home gardens and more milk cows and milk goats would greatly improve the diets of many families. On page 352 a table showing the distribution of vitamins in some common foodstuffs is given. In canning and drying fruits and vegetables, the vitamins are usually partially destroyed. Heating with an alkali (as in baking biscuit or corn bread with soda, or boiling vegetables with soda to make them tender) destroys the vitamins almost entirely.

Some Suggestions as to Diet. No hard and fast rules can be given for selecting a diet, but the following suggestions may be of aid:

1. *Eat meat, but only in moderation.* This will give the body some of the less common amino-acids furnished by meats and at the same time will permit other foods to be taken that will furnish bulk, minerals, and vitamins.

2. *Use plenty of milk.* This will supply high-grade protein, lime, and the fat-soluble vitamin.

3. *Eat vegetables, especially leaf vegetables.* These supply minerals, vitamins, and bulk. A varied diet is more likely to

FIG. 61. Starch grains in the cells of a potato. Raw starch is in hard little grains that are almost indigestible, but cooking causes the grains to soften and burst.

supply all the materials needed by the body than a restricted one, and the vegetables are the foods most likely to be eaten in insufficient amounts.

4. *Avoid an excess of sugar.* This not only deranges the digestion of many persons, but it supplies no protein, minerals, vitamin, or bulk. If much sugar is taken, other foods needed for a good diet are likely to be omitted.

5. *Eat enough food.* Enough should be eaten to keep up the weight and vigor of the body. It is estimated that about 30 per cent of children fail to take enough food (pages 353–355).

FIG. 62. A trichina lying among the muscle cells. It is found in pork, and pork should be thoroughly cooked before it is eaten.

The Cooking of Foods Cooking breaks up the cell walls of plants and the connective tissue of meats, thus causing these foods to fall to pieces more easily, so that the digestive juices have a better opportunity to do their work. Raw starch is in hard little grains that the enzymes can hardly penetrate and which are almost indigestible. Cooking causes these grains to soften, swell, and burst, making the starch readily digestible. Thorough cooking of meat is important to kill certain parasites that may be in it. Pork may contain a very tiny worm called the *trichina*, and the young of

the tapeworm is found in both pork and beef. If trichinæ are swallowed alive, they breed in the intestine and the young bore through the intestinal walls and reach the muscles, causing the disease called *trichinosis*. The young of the tapeworm fastens itself to the intestinal wall, absorbs the digested food, and grows into a long worm.

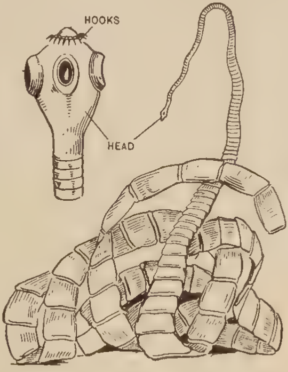


FIG. 63. Tapeworm. The young of the tapeworm is found in both pork and beef.

ALCOHOL AS A FOOD

The question is often asked whether or not alcohol is a food. On this point people continually disagree. One reason for the disagreement is that different definitions of the word "food" are used. A food is often defined as a substance which *can be burned in the body and will give energy to the body*. In this sense alcohol is a food, for in moderate amounts it is oxidized in the body and gives heat and strength to the muscles. The other definition of a food is that given on page 120. This definition insists that a food not only must furnish building material or energy, but also *must not injure the cells*. According to this definition, it is certain that alcohol in any but very small quantities is not a food, for it works great harm to the cells, especially to the nerve cells.

Whether or not alcohol in very small doses injures the cells, is very uncertain. If you took a drop of alcohol into your body, its effect would be so slight that you could not notice it. Even if it injured your cells, you would never

know it. If you took a spoonful of alcohol, probably you still could not notice any effect on yourself. But if you began the habit of drinking beer or wine or other alcoholic drinks, it is certain that you would get enough alcohol to injure your body decidedly. We do not discuss whether a very, very small amount of a poison like opium or belladonna would injure the cells, and whether these drugs give energy to the cells and are, therefore, foods. There is little more reason for discussing whether or not alcohol is a food; for, used in the amounts taken by any one who drinks alcoholic liquors, it is not a food but a poison.

Patent Medicines. Often we read, in advertisements, of medicines that will cure cancer, consumption, dyspepsia, and many others of our worst ills. These medicines will not do what is claimed for them. If there were any medicines that would cure cancer or consumption, the skillful physicians and scientists who are at the heads of our medical colleges and hospitals would know it, and they would be using them and telling every one about these wonderful remedies.

Some patent medicines contain opium, which is soothing and causes pain to be unnoticed, so that a person sometimes thinks he is better, when his disease has not been affected at all. Other patent medicines are very strong in alcohol, — as strong as, or stronger than, the most powerful alcoholic drinks. A dose of some of these medicines contains enough alcohol to affect the body decidedly, and the strengthening effect that persons sometimes think they feel when they use these "tonics" is nothing but the effect of the alcohol. Many patent medicines of course contain useful drugs, but without the advice of a physician it is unwise to take in among the delicate little cells of our bodies any strong medicine whose effects we do not understand.

QUESTIONS

Define a food. Why cannot coal be used for food? opium? What two points must we keep in mind in choosing our foods?

Name three causes of digestive disturbances. Discuss each of these. Give some rules for keeping the digestive organs in health.

What must an adequate diet supply? Into what are the proteins split before absorption? How do proteins differ as to the amino-acids they yield? Compare certain proteins as to their value for building purposes.

Discuss conflicting ideas as to the advantages and disadvantages of low- and high-protein diets. What article of food is usually eaten in abundance by those living on a high-protein diet? About how much protein is it probably wisest to take daily?

How much energy does a man doing moderate work require? At what time of life is most food needed? Why should carbohydrates and fats be used to supply the energy needs of the body?

What minerals are most frequently lacking in the diet? What foods supply minerals in greatest amounts? In what foods are minerals lacking? What method of cooking conserves the minerals in vegetables? What foods supply particularly large amounts of calcium? What foods should be included in the diet to make sure of a supply of vitamin?

Give four rules for the selection of food. How does cooking make foods more digestible? Why should pork and beef be thoroughly cooked before eating?

What two definitions are sometimes given for a food? According to which of these definitions is alcohol, except possibly in the very smallest quantities, not a food? Why is the discussion of whether or not alcohol is a food of little practical importance?

What injurious substances do some patent medicines contain? Why is it not advisable to take medicine without the advice of a physician?

REVIEW QUESTIONS

Chapter VII. Give two reasons why the body needs food. Of what is all matter composed? Of what are molecules composed? What is an element? a compound? Name the three classes of foods. Give examples of foods of each class. How do these food classes differ in chemical composition? Mention some other things that are necessary to the body.

Chapter VIII. Explain how a gland is formed and how it works. Draw a diagram of the digestive system and label the different digestive organs. What is the function of the stomach? of the gastric juice? How long is the small intestine? Name three secretions that are emptied into it. Describe the villi. What is their function? Name the accessory organs of digestion. Define: dentine; enamel; pulp cavity; incisor; canine; bicuspid; molar.

Name and locate the salivary glands. What is the use of the saliva? What glands of the digestive system are known to be affected by the nervous system? What mental condition is favorable to a good digestion? What trouble does alcohol cause in the stomach? in the liver?

Chapter IX. Why must food be digested? How are the food molecules changed in digestion? By what are they changed? Tell where the following enzymes are found, and what food each one digests: ptyalin; pepsin; trypsin; amylopsin; steapsin. To what are the proteins changed in digestion? the starches and sugars? Why must a cell have protein? What happens to the food molecules when the foods are oxidized within the cells? What becomes of the atoms that were in the food? What does a cell gain by burning food? What use is the fat in the body? What effect has alcohol on digestion? on the work of the liver?

Chapter X. Give some rules for keeping the digestive organs in health. Define a food. Give some causes of indigestion. How much energy is needed by the body daily? What foods supply minerals in greatest abundance? Give some rules for selecting a diet. How much protein is needed daily? Why, according to our definition of a food, is alcohol not a food? Why are patent medicines dangerous?

CHAPTER XI

THE CIRCULATORY SYSTEM

FROM the time we are born until we die, the heart beats. Day and night the blood flows through the body, passing out from the heart, streaming in among the cells, and hastening back to the heart. If because of disease or injury to the body the heart stops, the body dies. If the blood is weak and thin, the health of the body suffers, and if the blood is allowed to escape from the body, life at once ceases.

Why does the heart beat? Why is the blood kept flowing through the body? How does it help the cells to have the blood passing by them? Why are physicians so anxious that the blood be kept strong and pure and that nothing be done that will injure the heart? Why could not the body continue to live even though the heart should stop beating and the blood should cease to flow? To answer these questions intelligently, we must first of all understand the great laws according to which the body lives. Our bodies must have *food and water*, they must have *oxygen*, they must *get rid of their poisonous wastes*, and they must have an *even temperature*, neither too hot nor too cold. Our bodies are composed of cells, and each cell must have all of these things.

The Function of the Blood. The human body is a great colony of cells. The food and water for all the cells in the colony are taken in through the alimentary canal; but there must be some arrangement so that a cell in the brain or in

the foot can get the food that has been prepared for it by the digestive organs. Oxygen is taken in through the lungs; but the oxygen must be distributed all through the body to the cells. The poisonous wastes leave the body through the lungs and kidneys; but the wastes that are produced in the cells must be moved from the cells to the lungs and kidneys before they can be thrown out of the body. The heat of the body is produced by burning food within the cells; but in certain inner parts of the body, like the liver and muscles, there is too much heat, while in the outer parts of the body there is not enough heat. There must, therefore, be some way of distributing the body heat so that none of the cells will be either too hot or too cold.

The function of the blood is to carry food, water, and oxygen to the cells, to carry wastes away from the cells, and to carry heat from the warmer to the cooler parts of the body. As the blood flows among the cells it feeds them and gives them oxygen, picks up and carries away their wastes, cools the hot cells, and warms the cells that are too cold. The body may be very quickly killed by stopping the flowing of the blood among the cells.

THE CIRCULATORY ORGANS

The flowing of the blood through the body is called the *circulation.* The organs concerned in keeping up the circulation are the *circulatory organs.* These are the *heart* (Fig. 70), the *blood vessels* (*arteries*, *veins*, and *capillaries*), and the *lymphatic vessels* (Fig. 66).

The Heart. The heart[1] is usually about the size of the closed hand of the person to whom it belongs. It lies in the

[1] The heart is inclosed in a double-walled sac called the *pericardium.* (Fig. 82.)

thoracic cavity with its apex (point) to the left of the center of the body. The walls of the heart are composed of muscle cells, and within the heart are four cavities, — two upper cavities called *auricles*, and two lower cavities called *ventricles*. The auricles have thin walls, for their task is the small one of sending the blood down into the ventricles. The ventricles, on the other hand, have thick walls because they have the heavy work of forcing the blood through the body. *The function of the heart is to keep the blood circulating through the body.*

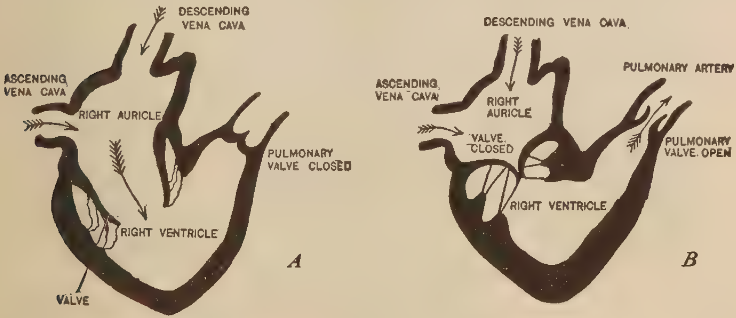


FIG. 64. Diagram of the right side of the heart showing the working of the valves. When the ventricle relaxes, the valves are as shown in *A*. When the ventricle contracts, the valves are as shown in *B*.

The Action of the Heart. Place your hand on your chest and you can feel the heart beat.[1] What is it doing when it beats? It is pumping the blood through the body.

The walls of the auricles first contract and draw inward on

[1] When the ventricles contract, the apex of the heart is pressed more forcibly against the wall of the chest. This causes the *beat*, which can be felt by placing the hand on the chest over the heart. The *pulse* that is felt in the arteries is a wave that travels out in the blood within an artery when the ventricles force the blood out of the heart.

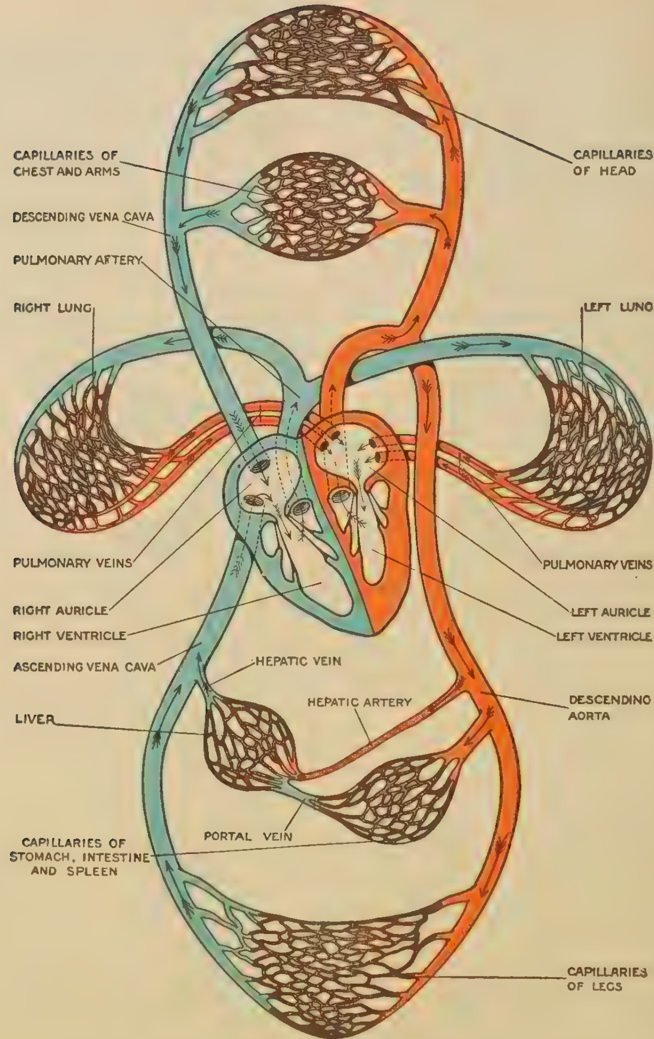


FIG. 65. Diagram of the circulation of the blood in the body.

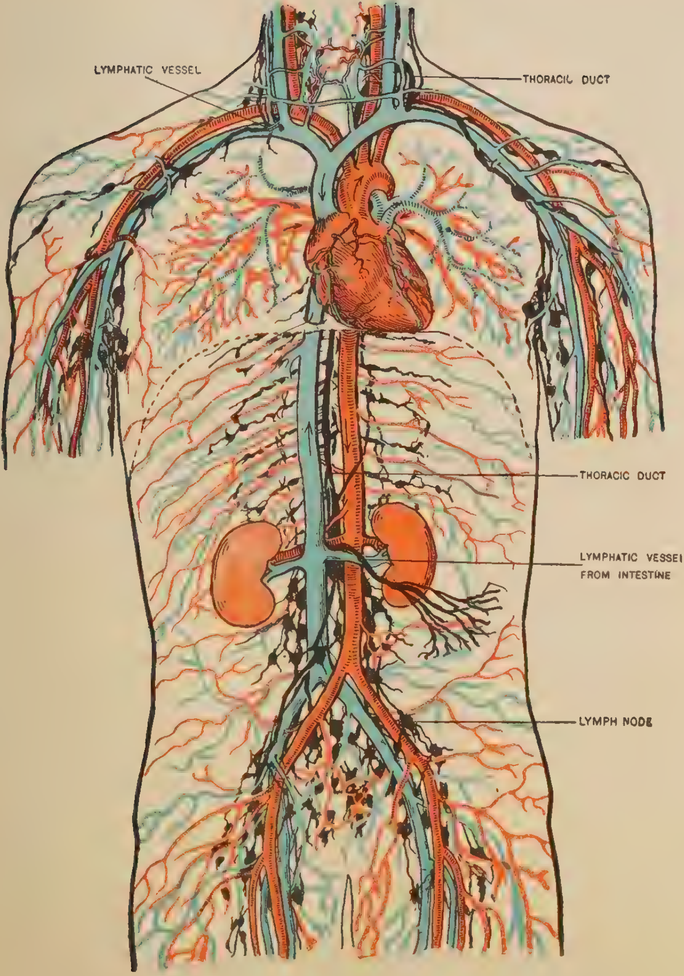


FIG. 66. The heart and the principal vessels of the body.

the blood, forcing the blood into the ventricles. The auricles then relax and the powerful walls of the ventricles contract, squeezing the blood out into the arteries. The ventricles now relax and for a moment the heart rests. Then the auricles again contract, completing the filling of the ventricles; the ventricles squeeze the blood out into the arteries, and so the process is repeated again and again. In one day the heart does as much work in sending the blood through the body as its owner would do in walking eight and one half miles on a level road.

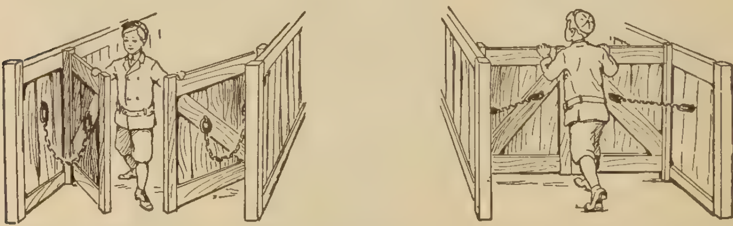


FIG. 67. These gates work like the valves of the heart. When the boy pushes on them one way, they open, but when he pushes on them the other way, the chains hold them so that they will not open.

The Rate of the Heart Beat. In an adult the heart usually beats from seventy to eighty times a minute. It is faster in women than in men, and varies in different individuals, some persons naturally having a faster heart beat than others. The rate of the heart beat varies also with age,[1] with rest and exercise, and with health and disease. You should count your own heart beat several times so that you will know its average rate. Then in sickness you will know how much it varies from its natural beat.

[1] The heart beat at different ages is about as follows: at birth, 130–140; first year, 115–130; second year, 100–115; third year, 90–100; seventh year, 85–90; fourteenth year, 80–85; adult life, 70–80; old age, 60–70; extreme old age, 75–80.

The Valves of the Heart. In the heart are four valves, two between the auricles and the ventricles (Fig. 64), and two at the openings of the great arteries (*aorta* and *pulmonary artery*), which lead out from the ventricles. All four valves are made of connective tissue, and *their function is to keep the blood from flowing backward.*

The valves between the auricles and ventricles work like little doors (Fig. 67) which open only downward into the ventricles. Little ligaments hold the valves so that they cannot be pushed upward into the auricles. The blood can therefore flow from the auricles into the ventricles, but when the ventricles contract, the blood pushes up under the valves and lifts them so that the openings between the auricles and ventricles are closed. Since the blood cannot pass back into the auricles, it must flow out into the arteries when the ventricle walls contract.

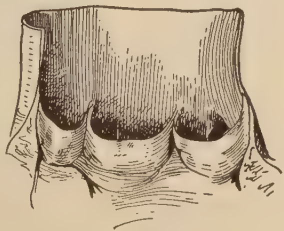


FIG. 68. The base of the aorta opened, showing the valves. When the blood starts to flow backward into the heart it catches in the pockets, which then swing out and close the opening in the aorta. See also Figure 64.

Each of the valves at the entrance to the great arteries is made of three loose pockets on the wall of the artery. The pockets open upward, and as the blood leaves the ventricles it readily flows over them. But when the ventricles relax and the blood starts to run back into the heart, the pockets fill with blood and hang out in the opening of the artery so that they touch each other. They thus close the passageway and keep the blood from flowing back into the heart.

Blood Vessels. *Arteries* are blood vessels in which the blood flows away *from* the heart. *Veins* are blood vessels in which the blood flows *to* the heart. *Capillaries*

are small vessels through which the blood flows *from the arteries to the veins.*[1] The two great arteries (aorta and pulmonary artery) that leave the heart divide into smaller arteries. These smaller arteries divide again and again, until finally they end in exceedingly small capillaries, which

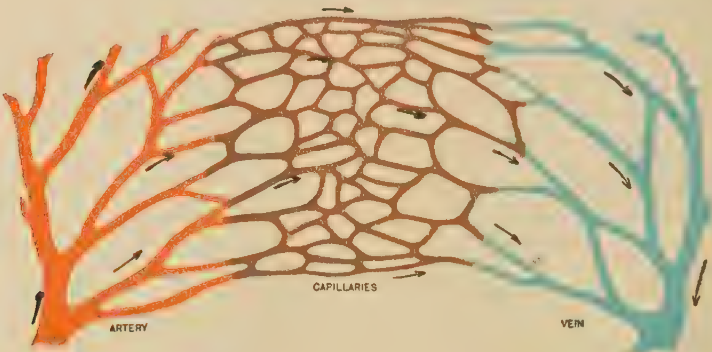


FIG. 69. The blood flows *from* the arteries *through* the capillaries *into* the veins.

are everywhere among the cells. After running in among the cells the capillaries begin to unite. More and more of them flow together and form small veins. The small veins continue to unite and form larger veins until they are joined into the large veins, the *venæ cavæ* and the *pulmonary veins*, which empty into the heart (Fig. 65). You must clearly understand that in the circulation the blood does not get out of the blood vessels, but passes through the capil-

[1] TO THE TEACHER: If a microscope can be procured, the teacher should not fail to have his pupils observe the fascinating sight of the blood corpuscles shooting along in the capillaries. One of the best places to see this is in the tail of a tadpole. Lay the tadpole on a flat piece of glass, and it will usually become quiet enough in a little while to allow the microscope to be focused on the capillaries.

laries from the arteries to the veins (Fig. 69). So abundant are the capillaries that the finest needle thrust into the body tissues cuts and breaks many of them.

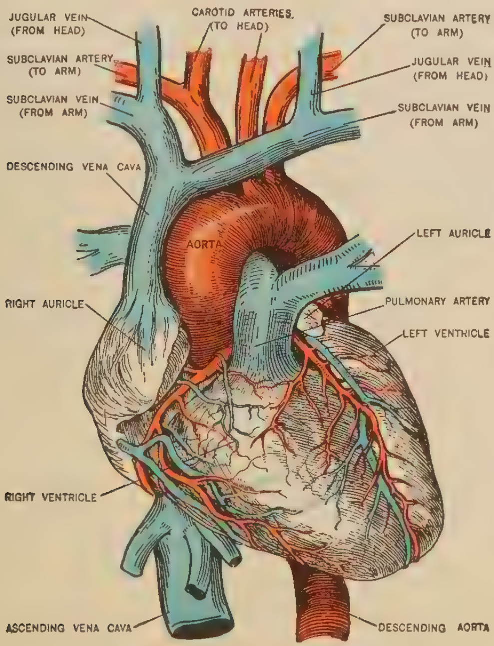


FIG. 70. The heart and the bases of the great vessels.

The Walls of the Blood Vessels. The walls of the arteries are composed chiefly of connective tissue and of muscle fibers which are placed circularly about the vessels. When the muscle fibers in the wall of an artery contract, they make the opening of the artery smaller, and a less amount of blood passes through it. By changing the size of the

arteries, some of the blood[1] can be cut off from a part of the body that is resting and needs only a little blood, and can be sent to a part of the body that is working and needs a larger blood supply.

The walls of the veins are thinner than the walls of the arteries, and have in them more connective tissue and less muscle. The walls of the capillaries are very thin, consisting of only one layer of thin flat cells and a few fibers of connective tissue.

The Course of the Circulation. The heart is a double organ. The right ventricle sends the blood through the lungs to the left auricle. The left ventricle sends the blood through the body to the right auricle. In a complete circulation the blood therefore passes twice through the heart. By studying the diagram on page 138, you will find that the course of the blood, beginning with the right auricle, is as follows:

From two great veins (the venæ cavæ) into the right auricle.

From the right auricle into the right ventricle.

From the right ventricle into the pulmonary artery and its branches.

From the branches of the pulmonary artery into the capillaries of the lungs.

From the capillaries of the lungs into four pulmonary veins.

From the pulmonary veins into the left auricle.

From the left auricle into the left ventricle.

From the left ventricle into the aorta and its branches.

From the branches of the aorta into the capillaries of the body.

[1] It is estimated that the capillaries of the intestine can hold all the blood in the body, and that if all the vessels in the body should relax at one time, it would take several times as much blood as there is in the body to fill all of them.

From the capillaries of the body into the smaller veins.

From the smaller veins into the two great veins[1] called the ascending and descending venæ cavæ, and then back into the right auricle.

Day and night the blood circulates through the body, passing out from the heart through the arteries, flowing through the capillaries and returning to the heart by way of the veins. Day and night the heart pumps away,[2] keeping the current of blood flowing through the vessels. No other organ of the body is so hard-worked as the heart, which pauses to rest only between its beats.

The Nervous Control of the Circulation. The heart has two sets of nerves, — one set quickening its beat and the other set causing it to beat more slowly. Through these nerves, the rate of the heart beat is controlled.

The muscles in the walls of the arteries are also supplied with two sets of nerves. One set of nerves causes the muscles in the arterial walls to contract, and one set causes

[1] From the diagram on page 138 it can be seen that the *portal* circulation, or the circulation through the liver, is peculiar in that the blood passes through *two sets of capillaries*. The blood that has passed through the capillaries of the stomach, intestine, pancreas, and spleen is collected into one great vein (the *portal* vein) and taken to the liver, where it again spreads out in the capillaries among the liver cells. It is then collected into the *hepatic* vein and goes on to the heart. Sugar is stored in the liver, and the advantage of this arrangement is that the blood carrying the absorbed sugar passes through the liver before it goes to the rest of the body. The blood that comes to the liver through the portal vein has lost its oxygen in the first set of capillaries, so the liver has another supply of blood coming to it through the *hepatic* artery (page 138) to furnish it with oxygen.

[2] The circulation time of the blood through the body (from left ventricle to right auricle) is on an average something like a minute. The circulation time through the lungs (from right ventricle to left auricle) is about twelve or fifteen seconds. This means that twice in every minute and a quarter the heart must pump all the blood in the body through itself.

them to relax. The size of the openings in the arteries, and the amount of blood going to the different parts of the body, can thus be regulated by the nervous system. When a person blushes, the little arteries in the skin of the

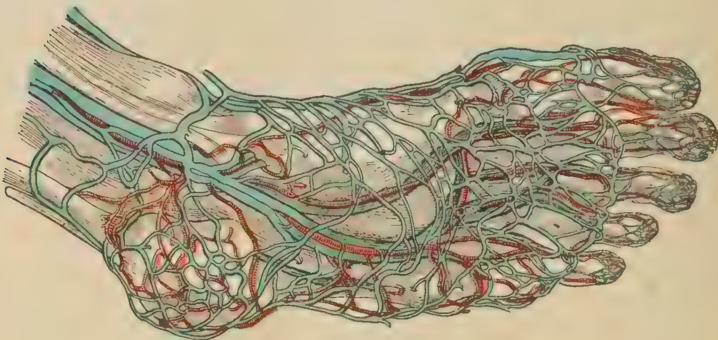


FIG. 71. The vessels of the foot. Only a few of the arteries are shown.

face open and allow a larger quantity of blood to come into them. From this you can understand how quickly the size of the arteries can be changed, and, when you think of the cause of blushing, you will know that the muscles in the blood vessels can be affected by the nervous system.

THE BLOOD AND LYMPH

The blood makes up about one nineteenth of the body weight. It is composed of a liquid part, the *plasma*, and of red and white blood *corpuscles* that float in the plasma. On an average about five million red corpuscles and ten thousand white corpuscles are found in a drop of blood the size of the head of a pin. There are, there-

fore, about five hundred red corpuscles to one white corpuscle.

The Plasma. The blood plasma is composed mainly of water. Dissolved in the plasma are the different foods, salts, and other materials used by the cells. *The function of the plasma is to carry foods and wastes, and to form a liquid in which the corpuscles can float about in the blood vessels.*

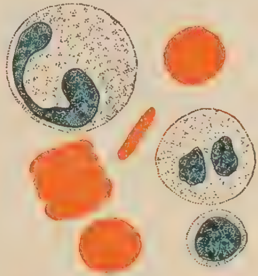


FIG. 72. Red and white blood corpuscles.

The White Corpuscles. The white corpuscles can change their shape. They are the only cells of the body, except the muscle cells, that have the power of movement,[1] and more than any other of our cells they resemble the little one-celled animals about which we studied in the first chapter. They often escape from the capillaries by passing through between the cells of the capillary wall (Fig. 73). For a long time it was thought that the white corpuscles had no definite work to do, but roamed about while the other cells were busy, each at its particular task. Now it is known that *the function of the white corpuscles is to kill the disease germs which get into the body among the cells* (Fig. 137).

The Red Corpuscles. The red corpuscles are small, circular disks with a hollow in each side, as you see in Figure 72. Most of them are formed in the marrow of the spongy bone (page 42). Here some of the cells lose their nuclei, take on the shape of corpuscles, and by and by float away in the blood stream as red corpuscles. For some time they circulate through the blood vessels, but finally die and

[1] On ciliated cells (Fig. 6) the cilia move, but the cells as a whole do not.

are broken up, chiefly in the spleen. Part of the broken down materials of the red corpuscles leave the body as the coloring matter of the bile. It is estimated that every day about fourteen billions of red corpuscles die in the body, and as many new ones are formed.

FIG. 73. A white corpuscle escaping from a capillary.

The Function of the Red Corpuscles. *The function of the red corpuscles is to carry oxygen and to assist the plasma in carrying carbon dioxid.* The way in which the red corpuscles carry oxygen is very interesting. They have within them a substance called *hemoglobin*. When this is exposed to oxygen, as it is in the lungs, each molecule of the hemoglobin unites with a molecule of oxygen and carries the oxygen away with it. Then, when the corpuscle goes out in the capillaries among the cells, the hemoglobin [1] gives up its oxygen to the cells (Fig. 74).

The carbon dioxid is dissolved in both the plasma and the corpuscles. It does not, however, unite to any extent with the hemoglobin of the corpuscles, as the oxygen does, and a corpuscle can carry both

[1] The way the oxygen is carried in the blood may be represented by comparing the blood to a stream, the red corpuscles to little boats in the stream, and the hemoglobin molecules to little jars in the boat. In the lungs a molecule of oxygen is placed in each of the jars; out in the capillaries of the body the oxygen is emptied out of the jars, and the little boat floats around to the lungs, where each jar is again loaded with a molecule of oxygen.

carbon dioxid and oxygen at the same time.[1] The carbon dioxid injures the cells because it is itself poisonous, and not by keeping the corpuscles from carrying oxygen to them.

The Color of the Blood. Blood containing oxygen is bright red in color, and blood without oxygen is dark, appearing blue in the veins under the skin. This you can see by looking at the veins in your forearm, which bring the blood from the hand back to the heart. The blood gets its oxygen in the lungs (Fig. 81) and loses it in the capillaries of the body. The blood is therefore red in the pulmonary veins, in the left side of the heart, and in the aorta and all its branches. It is dark in the veins bringing the blood from the body to the heart, in the right side of the heart, and in the pulmonary artery. The same thing can be said more briefly thus: The blood is *red* while going *from the lungs* to the body capillaries, and *dark* while going *to the lungs* from the body capillaries.

The Lymph. The blood plasma soaks through the thin walls of the capillaries and passes out among the body cells. After the plasma gets outside the capillaries it is called *lymph*. The lymph surrounds all the cells in the body and fills all the little spaces between the cells. A fresh supply of lymph is constantly escaping from the blood, and the amount of lymph in the body is several times as great as the amount of blood.

The Function of the Lymph. *The function of the lymph is to receive food and oxygen from the blood and pass them on to the cells, and to receive the wastes from the cells and pass them*

[1] In suffocation from gas, death is usually caused by a gas called carbon monoxid (CO). This unites very firmly with the hemoglobin, and when the blood comes to the lungs, the corpuscles cannot take up the oxygen.

to the blood. The cells of the body, except the blood corpuscles, lie outside the blood capillaries. The food and oxygen must pass out of the blood capillaries before they can reach the cells. This the food and oxygen do by passing out through the capillary walls into the lymph, and then through the lymph to the cells. In the same way the wastes reach the blood, passing out of the cells into the lymph, and from the lymph into the blood. *The lymph is therefore a middleman between the cells and the blood.*

FIG. 74. As the blood flows through the capillaries it gives food and oxygen to the cells and takes wastes from the cells. The lymph acts as a middleman between the cells and the blood.

The Cells in the Body surrounded by Liquid. Each cell of the body lives in a liquid (the lymph) as truly as does a little one-celled animal that lives in a pond of water. The one-celled animal takes its oxygen and food from the water, and its wastes pass out into the water. The cells of the body take their food and oxygen from the lymph, and discharge their wastes into it. In the pond, however, there is an abundance of food and oxygen for the little animal, and the amount of water in the pond is so great

FIG. 75. Muscle cells and the blood capillaries that nourish them. These cells are surrounded by lymph as are the cells in Figure 74.

that the wastes have little effect on its purity. In the body, on the other hand, the cells are so closely crowded that they would in a very short time use all the food and oxygen in the lymph, and fill it with poisonous wastes. There must therefore be some way of constantly sending into the lymph a fresh supply of food and oxygen, and of constantly carrying away the wastes; and this, as we have seen, is done by the blood.

THE LYMPHATIC SYSTEM

Since the plasma is continually escaping from the blood capillaries, there must be some way of carrying the lymph away from among the cells; otherwise too much lymph would collect in the tissues and the body would become swollen with liquid.[1] The lymph cannot go back into the blood capillaries against the current of escaping plasma, so there is another system of vessels (Fig. 78) to drain it away from among the cells. The vessels that do this are called the *lymphatic* vessels, and their function is *to collect the lymph from among the tissues and carry it again to the blood.*

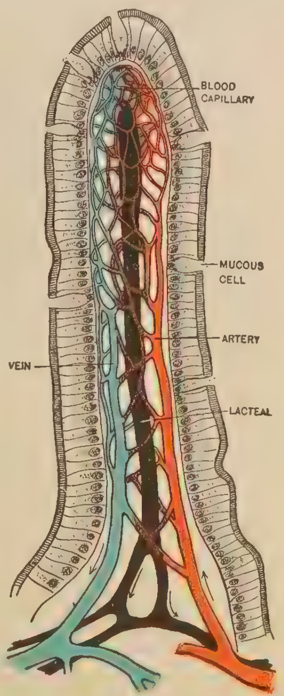


FIG. 76. A villus and its vessels. The lymphatic vessels (lacteals) are in black.

The Lymphatic Vessels. The lymph flows into the lymph capillaries, which form a thick network

[1] In dropsy the lymph collects in the tissues and causes great swelling.

among the cells. The capillaries unite and form larger vessels, which finally empty the lymph back into the blood. The lymphatic vessels from the right arm and the upper part of the right side of the body empty into a vein in the right shoulder (Fig. 66). The lymphatic vessels of the remainder of the body empty into the *thoracic duct*. This

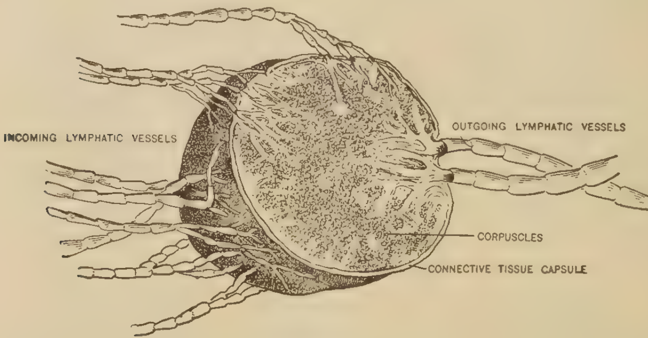


FIG. 77. A lymph node. The lymph filters through among the white corpuscles in the node.

vessel is about the size of a slender pencil and runs up the back of the ventral cavity, bending over at the top, and emptying into a large vein deep in the left shoulder. Thus the lymph that escapes from the blood capillaries is taken up by the lymphatic vessels and brought back to the blood.

The Lymphatics of the Small Intestine. Besides taking up the escaped plasma from among the cells, the lymphatic vessels[1] in the small intestine do another work. The digested foods — sugars, proteins, and fats — all pass through the walls of the villi (page 93), but to get into the blood the fats

[1] The lymphatics of the small intestine are called *lacteals*.

travel a different road from the others. *The sugars and proteins pass into the blood capillaries of the villi* (Fig. 76). *The fat enters the lymph capillaries*, and is carried to the thoracic duct, which empties it into the blood.

The Lymph Nodes. Scattered through the body are many[1] white bodies, called *lymph nodes*. The largest of them are perhaps as large as an ordinary sized marble, though somewhat flattened. If you should examine a lymph node, you would find that it has a connective-tissue coat and that it is filled with white corpuscles. The lymphatic vessels pour the lymph into these nodes, where it filters through among the corpuscles in the node much as water filters through sand grains. After passing through the node, the lymph is taken up and carried on by other lymphatic vessels. The lymph from many parts of the body passes through several nodes before it reaches the blood.

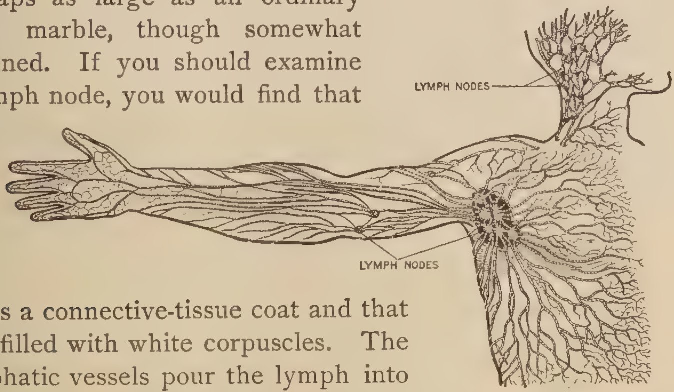


FIG. 78. The lymphatic vessels and nodes of a part of the body.

The Function of the Lymph Nodes. The lymph nodes have two functions: *they furnish breeding places for the white corpuscles, and they filter out disease germs that get in among the cells and are taken up by the lymphatic capillaries.*

[1] There are six or seven hundred lymphatic glands in the body large enough to be seen without a microscope (Fig. 66).

The white corpuscles that escape from the blood enter the lymphatic capillaries and are carried to the lymph nodes. Inside the nodes they divide and form new corpuscles. The corpuscles reach the blood again by passing into the vessels that flow from the nodes and floating in the lymph to the blood.

Many diseases are caused by germs that live and grow among the cells. Some of these germs are taken up by the lymph capillaries and carried into the lymph nodes. The nodes stop the germs, and the corpuscles in the nodes kill them. Thus the germs are kept from getting into the blood and being carried all through the body.[1]

HYGIENE

The heart is a muscle, and it is by far the hardest worked of all the muscles of the body. It is especially hard-worked at that period in life when growth is very rapid, — when a boy or girl, in a single year, becomes almost as large as a man or a woman. Any extra strain put upon the heart at this time is very likely to cause trouble. The heart also becomes weak in old age, and old persons should take care not to overwork their hearts. The following are the chief causes of injury to the heart:

Severe Exercise. Exercise of the muscles greatly increases the work of the heart. Hard work causes any muscle to enlarge, and the extra work thrown on the heart by severe exercise may cause "athletic heart." In this condition the

[1] In cancer, "cancer cells" are carried into the lymph nodes that receive the lymph from the diseased tissue, and set up their growth there. It is impossible to treat the disease successfully after the cancer cells have reached the lymph nodes that lie deep in the body. It is important, therefore, that a physician be consulted at the earliest possible moment.

heart is enlarged, sometimes to several times its natural size. This enlarging of the heart is frequently followed by a relaxation of the heart and of the arterial walls. The openings where the valves are placed are enlarged until the valves do not completely close them. The valves then leak and part of the blood flows backward in the circulation. This blood must be pumped twice, so the work of the heart is increased. Very hard work may also cause fatty degeneration of the heart.

Boys often injure their hearts by bicycle riding. Football sometimes injures the heart, requiring too long-continued and too severe exercise for any but those with naturally strong hearts. Too much playing of tennis may also overtax the heart, and any other severe and long-continued exercise may do the same. It is well to keep in mind that the time of life when the heart is most frequently injured is in youth.

Headache Remedies. A great number of headache remedies are manufactured from coal tar. They are powerful depressors of the heart, and many people have injured their hearts with them. They are useful medicines, but very dangerous to take except under the advice of a physician.

Alcohol. The effects of alcohol on the heart and blood vessels are very serious. It sometimes causes a paralysis of the muscles in the small vessels, so that they are always distended with blood, as you may have seen in the face and eyes of one who uses alcohol excessively. It weakens the arteries by causing a fatty degeneration and a hardening of the arterial walls. Apoplexy (the bursting of a blood vessel in the brain) is therefore more frequent among alcoholics than among abstainers from alcohol. Alcohol also sometimes causes great quantities of fat to be deposited upon the heart, thus interfering with its work; it so affects the

nervous control of the heart that the action of the whole organ is weakened.

The use of alcohol also overworks the heart. It takes more force to pump the blood out of the heart into hard, stiff-walled vessels than is required to pump it into vessels with elastic walls. The work of the heart is therefore increased when the arterial walls are hardened by the use of alcohol. This, like hard exercise, overworks the heart, and brings on enlargement of the heart, trouble with the valves, and fatty degeneration. Beer drinkers in particular suffer from heart disease, because in addition to enduring all the evil effects of alcohol, a beer drinker's heart is required to pump through the system the great quantities of water taken in the beer.

Of course, from reading the above you are not to understand that every one who takes alcohol into his body must have all these diseases of the heart. You are to understand, however, that the effects of alcohol on the heart are bad, and that heart disease is much more common among those who use alcohol than among those who abstain from alcohol. With such an important organ as the heart, no one can afford to take the chance of weakening it in any way, for even though in health it may seem to be doing its work without difficulty, in an attack of pneumonia or other severe illness, when everything depends on the heart's holding out for a few days longer, it may suddenly fail. Statistics from a European hospital show that 16 per cent of all deaths in the hospital were due to "beer drinker's heart," the weakened hearts failing under the strain of disease.

Tobacco. Tobacco so affects the heart nerves that the action of the heart becomes unsteady,—sometimes beating very hard and fast, and sometimes with a weak, fluttering

beat. This trouble is known as "tobacco heart," and is very common among young cigarette smokers.

Summary. The body cannot live without the circulation of the blood, because it is the blood that carries the food, oxygen, and water to the cells, takes away the wastes from the cells, and distributes the body heat.

The blood is pumped through the body by the heart. It leaves the heart through the arteries, passes through the capillaries, and comes back to the heart through the veins. As it passes through the capillaries it gives food and oxygen to the cells and takes up the cell wastes.

The blood is composed of corpuscles and plasma. The plasma escapes through the capillary walls and passes out among the cells. It is then called lymph. The lymph is taken up by the lymphatic vessels and returned to the blood.

The heart is sometimes injured by too severe exercise, headache remedies, alcohol, and tobacco.

QUESTIONS

Give three great laws according to which the body lives. What is the function of the blood? Explain why the circulation of the blood is necessary.

What are the circulatory organs? Locate and describe the heart. Of what are the walls of the heart composed? How many cavities are in the heart, and what are they called? Why are the walls of the ventricles thicker than the walls of the auricles? What is the function of the heart?

Describe a contraction of the heart. What is the average rate of the heart beat? How fast does your own heart beat?

Where are the valves in the heart? What is their function?

Describe the way the valves in the heart close the openings between the auricles and the ventricles; the way they close the openings from the arteries into the heart.

What is an artery? a vein? a capillary? How does the blood flow in each of these vessels? How does it get from the arteries into the veins?

How do the walls of arteries, veins, and capillaries differ? How is the size of the opening in an artery changed? What advantage is this to the body?

Trace the course of the blood from right auricle to right auricle. How long does it take the blood to make this circuit?

What two sets of nerves are connected with the heart? with the arteries? What proof can you give that the blood vessels are controlled by the nervous system?

How much of the body weight is blood? Of what is blood composed? What is the liquid part of the blood called? What two kinds of corpuscles are in the blood? How abundant are the red corpuscles? the white?

What is the function of the plasma? Where are the white corpuscles formed (page 153)? Explain how they escape from the capillaries. What is the function of the white corpuscles?

What shape has a red corpuscle? Where are the red corpuscles formed? What becomes of them? What is their function? What substance in them carries the oxygen? Explain how it does this. How is carbon dioxid carried in the blood? Why is carbon dioxid injurious to the cells?

Where in the body is the blood red? Where is it dark? What is lymph? What is the function of lymph? How does the life of one of the body cells resemble the life of a small animal in a pond of water?

What is the function of the lymphatic vessels? Where do the vessels from the upper part of the right side of the body empty into the blood? What vessel drains the lymph from the remainder of the body? Where does this vessel empty into the blood? How do

the absorbed sugar and proteins reach the blood? How do the absorbed fats reach the blood?

Describe a lymph node. How is the lymph carried into and through it? What two functions have the lymph nodes?

At what times of life is the heart especially likely to be injured? Why does too severe exercise hurt the heart? In enlargement of the heart, what trouble is there with the valves? What effect has this on the amount of work the heart must do? Name some of the forms of exercise that are likely to injure the heart.

What effect have headache remedies on the heart? What effect has alcohol on the small vessels? on the walls of the arteries? What does this sometimes cause? What does alcohol cause to be deposited about the heart? How does alcohol increase the work of the heart? What additional work does a beer drinker's heart have? Why is it unsafe to risk injuring the heart? What per cent of deaths in a European hospital were due to beer drinker's heart? What is the effect of tobacco on the heart?

Press on a vein in your wrist with one finger. On the side of the finger toward the heart empty the vein by rubbing another finger along it. Does the blood flow back into the vein? On the other side of the finger that is pressing the vein, rub the blood away from the heart. Does the blood flow back into the vein? Explain.

Explain why a steady stream of water comes out of the end of a long rubber hose into which water is being pumped with intermittent strokes. The blood in the arteries flows in spurts, and in the capillaries and veins it flows in a steady stream. Explain why it does this. Why does it require more force to pump water into an iron pipe than into a rubber hose with elastic walls?

Does a wave on a river travel with the same speed as the water in the river? Do the blood and the wave in the blood that causes the pulse in an artery, travel with the same speed?

CHAPTER XII

RESPIRATION

WATCH the chest of some one who is near you, and you will see that it alternately rises and falls. As the chest rises, air is taken into the lungs. This is called *inspiration.* When the chest falls, the air is driven out of the lungs. This is *expiration.* The whole process of taking the air into the lungs and sending it out of them is called breathing, or *respiration.* Like the circulation of the blood, respiration goes on night and day as long as the body lives.

The Object of Respiration. *The object of respiration is to take oxygen into the body and to give off carbon dioxid from the body.* When the blood passes through the lungs, it takes up a new oxygen supply for the cells, and loses the carbon dioxid which it has carried away from the cells. Without respiration, the circulation of the blood would be useless, for the blood could not obtain oxygen, and it would carry through the body again and again the poisonous carbon dioxid which it takes up from the cells.

FIG. 79. Burning low for lack of oxygen.

Why Oxygen is Necessary to the Cells. When the foods are oxidized (burned) within the cells, the atoms of the foods unite with atoms of oxygen. By this process, energy is given to the cells (page

114). If there are no oxygen atoms in the cells for the food atoms to unite with, it is evident that the oxidation of the foods within the cells must come to a stop. The cells will then be unable to get energy, and they will die. Without oxygen they cannot use the food, and without oxygen they starve to death for lack of energy as surely as if no food had reached the cells. *Oxygen is necessary that the foods may be burned within the cells.* As oxygen is necessary for the burning of the foods within the cells, so it is necessary for the burning of all substances everywhere. Cover a candle by setting a glass vessel over it (Fig. 79). In a few moments the candle will go out because there is no more oxygen in the vessel.

THE ORGANS OF RESPIRATION

The organs of respiration include the *framework of the chest*, the *muscles that are used in breathing*, the *lungs*, and the *air passages*. The lungs are the most prominent of these organs, and it is in them that the blood gives off its carbon dioxid and takes up its oxygen. Most of the diseases of the respiratory organs are caused by germs that grow on the warm, moist lining of the air passages, and in the air sacs of the lungs.

The Lungs. The lungs (Fig. 84) are composed chiefly of a great mass of air passages and air sacs. They therefore have a light and spongy structure. In the lungs blood vessels are very abundant, for at each beat of the heart as much blood goes to them as goes to all the remainder of the body. The lungs are hung in the thoracic cavity by the trachea (Fig. 82), through which air passes into and out of them. Each lung is surrounded with a thin connective tissue sac called a *pleura* (plural, *pleuræ*).

The Thoracic Cavity. The thoracic cavity (Fig. 8) lies within the framework of the chest, and the diaphragm[1] forms its floor. It is divided longitudinally into three chambers (Fig. 80). In each side chamber lies a lung. In the central chamber the heart and the bases of the great blood vessels, the trachea, and the esophagus are found. The central chamber is wider in its lower front portion where the heart lies, and narrower above and behind the heart.

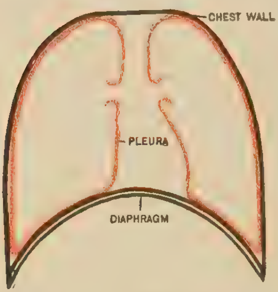


FIG. 80. The divisions of the thoracic cavity.

The Pleuræ. The *pleuræ* are two thin, double-walled sacs. The outer layer of a pleura is attached to the chest wall and diaphragm, and stretches as a partition across the thoracic cavity from top to bottom. The inner layer incloses the lung. This layer of the pleura is very delicate, and forms a thin coat over the surface of the lung. In Figure 80 you can see how the chest cavity is divided into three parts by the pleuræ, and in Figure 82 you can trace a pleura entirely around a lung and around the

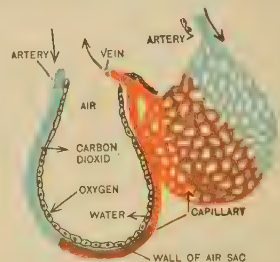


FIG. 81. Air sacs and blood vessels in the lungs. The blood capillaries lie in the thin walls of the air sacs. As the blood passes through the capillaries carbon dioxid and water pass out into the air sac, and oxygen passes from the sac into the blood.

[1] The diaphragm (Fig. 8) is a thin sheet of muscle with a connective tissue center. It is dome-shaped, the stomach and liver fitting into the hollow in its lower surface. Viewed from above, the diaphragm appears *as a ring of muscle with a connective tissue center*. It is attached all around by its outer edge to the body wall, specially heavy bands of muscles running down and attaching them-

cavity in which the lung lies.[1] The surfaces of the pleuræ are kept moist with a thin yellowish liquid.[2] This prevents friction when the two layers of the pleura move on each other in breathing.

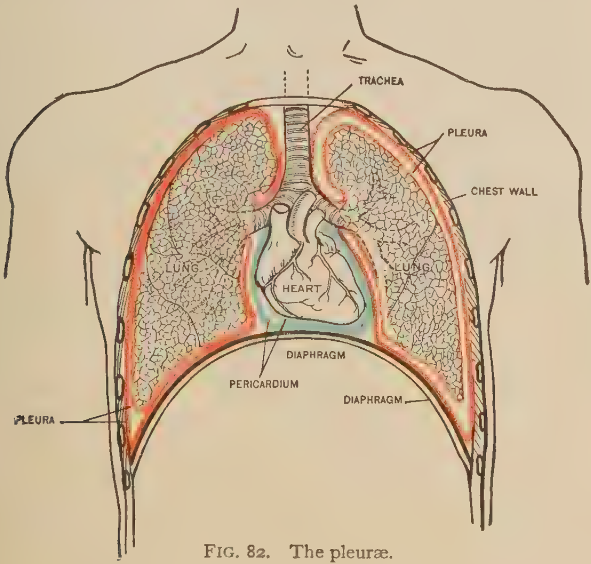


FIG. 82. The pleuræ.

How the Chest is enlarged in Inspiration. In inspiration the chest is enlarged in two ways. *The ribs and sternum are lifted up and out,* widening the cavity of the chest. *The diaphragm is drawn downward,* causing the bottom of the chest cavity to sink, and thus increasing the size of the cavity. The

selves to the front of the spinal column. When the muscles of the diaphragm contract and shorten, they draw its top (center) downward.

[1] The pupil should also trace out the course of the pericardium and note that it is a double-walled sac enveloping the heart as a pleura envelops a lung.

[2] The disease called pleurisy is inflammation of the pleuræ. In this disease considerable quantities of liquid may collect between the two layers of the pleuræ

chest walls and the diaphragm are thus drawn away from the lungs, leaving a *vacuum*, or empty space, between the two layers of the pleuræ. The air then rushes down into the lungs, and expands them until they fill the enlarged thoracic cavity. So promptly do the lungs expand and follow up the chest walls and diaphragm in inspiration that there is no noticeable space between the two layers of the pleuræ.

Expiration. In ordinary expiration, the muscles do little work. The ribs and sternum sink chiefly from their own weight, and the diaphragm is pushed [1] up by the liver, stomach, and other abdominal organs below it. This with the *elasticity of the lungs* drives out the air; for just as the stretched walls of a blown-up football or of a toy balloon expel the air, so the stretched walls of the air sacs and of the small bronchial tubes help to force the air out of the lungs.

The Nasal Passages and the Pharynx. When air is taken into the lungs, it first enters the nasal passages (Fig. 83). These are two narrow chambers that run up in the head as high as the eyes and backward about four inches. An opening in the floor of each nasal chamber at the back leads down into the pharynx.

The pharynx is a funnel-shaped cavity lying behind the mouth. It curves around the base of the tongue, with its mouth opening forward. Hanging down in front of the openings from the nasal chambers and helping to separate the mouth from the pharynx is a little curtain-like structure called

[1] When the diaphragm comes down in inspiration, it forces the organs below it downward and pushes the abdominal walls outward. In expiration the stretched abdominal walls come inward partly because of their elasticity, and partly because of the contraction of the abdominal muscles, and drive the diaphragm upward. In a forced expiration, the abdominal muscles contract forcibly, pulling in the abdominal walls and driving the diaphragm far upward. At the same time they draw down the ribs and sternum, to which they are attached at their upper ends.

the *uvula*, or *soft palate*. In swallowing, the uvula is pushed back over the openings from the nose so that it covers them and prevents food and water from entering the nose (Fig. 83).

In the side walls of the pharynx, directly under the corners of the lower jawbone, the two *tonsils*[1] are located. When viewed from the inside of the pharynx, the tonsils appear like gentle, rounding elevations lying under the mucous membrane which lines the pharynx walls. At the bottom of the pharynx are two openings, one leading into the esophagus and one into the larynx.

The Larynx. The larynx is the enlarged upper part of the trachea. It has a framework of cartilages, which you can easily feel in the front of your neck. In swallowing, the food and drink would fall down into the larynx if it were not for the *epiglottis* (Fig. 83). This flap-like structure stands in front of and above the opening to the larynx, and in swallowing the larynx is drawn up and forward,[2] so that its mouth is pushed up in under the epiglottis. The food or water then passes over the larynx into the esophagus. During breathing the larynx drops down, leaving its mouth open, and allowing the air to pass into and out of the lungs. The *vocal cords*, which produce the sound of the voice, are in the larynx.

The Trachea and its Branches. The trachea divides into two great branches, one of which goes to each lung. Within the lung these branches divide again and again, until finally they end in little air sacs. The branches of the trachea are

[1] When germs get into the tonsils and cause inflammation, the disease is called *tonsillitis*.

[2] Feel your larynx while you swallow, and note how it rises. If one laughs when eating or drinking, the larynx is lowered and food or water may fall down into the trachea. When food or liquid is driven upward through the pharynx in laughing or by vomiting, it may pass in behind the uvula and enter the nasal passages from the rear.

called the *bronchial tubes*. In the walls of the trachea and of all the larger bronchial tubes are rings of cartilage to keep the air passages from closing and shutting off the supply of air[1] from the air sacs in the lungs.

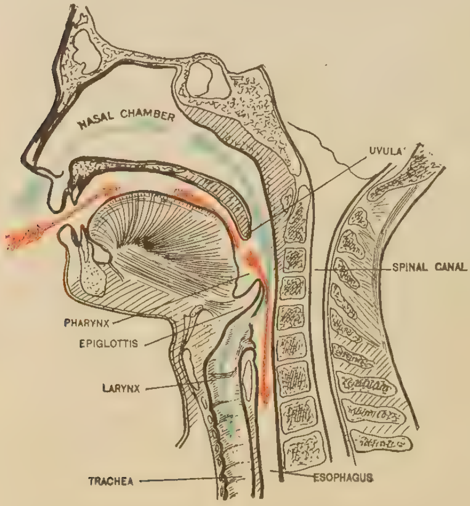


FIG. 83. The air follows the path indicated by the blue arrows, and the food follows the path indicated by the red arrows.

The Air Sacs. Each small bronchial tube at the end widens out and becomes a thin-walled sac. The walls of this sac are thrown into little sac-like folds, so that the end of a bronchial tube is a larger sac[2] made up of a great number of little sacs, all opening inward toward the center. So abundant are the air sacs in the lungs that their estimated number is 725,000,000, and if they were all opened and spread out side by side, they would cover 2150 square feet of space.

Changes in the Air in the Air Sacs. The walls of the air sacs are exceedingly thin. They contain a very great

[1] In asthma the muscles in the walls of the small bronchial tubes contract so that the greatest difficulty is experienced in getting the air to pass in and out of the air sacs. In pneumonia the small air passages and the air sacs are stopped up with mucus and blood.

[2] The larger air sacs at the ends of the bronchial tubes are called *infundibula* (singular, *infundibulum*). The smaller air sacs of which an infundibulum is composed are called *alveoli* (singular, *alveolus*).

number of delicate blood capillaries through which all the blood in the body passes every minute and a quarter (page 145). As the blood flows through the capillaries in the walls of the air sacs, oxygen from the air passes in through the walls of the sacs and enters the blood, and carbon dioxid

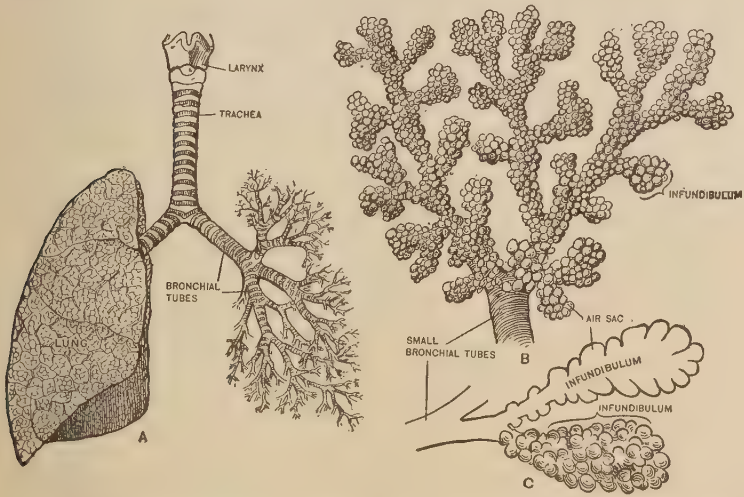


FIG. 84. The trachea and the lungs. *B* and *C* show the way the small bronchial tubes end in air sacs (*infundibula*) which are made up of a large number of smaller sacs.

passes out from the blood into the air (Fig. 81). Water also passes out of the blood into the air, as you can prove by breathing on a cold window pane, and the air is warmed while in the lungs. The air in the lungs, therefore, loses oxygen, and gains carbon dioxid, water, and heat.

Perhaps what is going on in the lungs would be made more vivid to you, if, in imagination, you could make a trip down into the lungs and see what is happening there. Following down the trachea and the bronchial tubes, you would come into one of the larger air sacs

There you would see all about you the mouths of the little air sacs opening into the chamber in which you were standing. Going up to the mouth of a small sac and looking in, you would see the blood shooting along in the capillaries in the walls. As the blood enters the capillaries, it is dark in color, but as it moves along it gradually takes on a redder and redder hue until it is a bright scarlet when it gets through the capillaries and starts to the heart.

Peering still more closely into the sac, you would see a great multitude of little oxygen molecules flying from the air into the blood, where they unite with the hemoglobin of the red corpuscles and are carried away. You would also see the carbon dioxid and water molecules flying out from the blood into the air in the little sac, and then passing out into the larger sac and up into the bronchial tubes, to pass out of the lungs in the breath.

Mucus and Cilia. The entire respiratory tract is lined with mucous membrane and is kept moist with sticky mucus. In all parts of it except in the pharynx and air sacs and over the vocal cords, the walls are covered with cilia (Fig. 6).

The mucus on the walls of the air passages catches dust and germs that are in the air, and the cilia sweep the mucus and matter which is caught in the mucus out of the air passages. The air is thus cleansed, and irritating dust particles and dangerous disease germs are in a great measure prevented from getting down into the delicate air sacs of the lungs.

The nasal passages are especially fitted for purifying and warming the inhaled air. The nostrils are guarded by hairs for straining out dust, the mucus on the walls of the long and narrow nasal passages catches much dust and many germs, and air inhaled through the nose is warmed before it reaches the throat and lungs. Any trouble in the nasal passages[1]

[1] Nasal polyps close the passage through the nose, and adenoids (spongy growths above and behind the uvula) block the openings from the nose to the throat. The teacher should report to the parents all children who have trouble in breathing through the nose (pages 253, 270).

that interferes with breathing through the nose should receive medical attention at once, for in mouth breathing, cold and dusty air is taken into the throat and lungs. This brings on many diseases of those parts.

RESPIRATION IN OTHER ANIMALS

An insect has no lungs, but it takes in air through a great number of little tracheæ, or air tubes, which open along the sides of its body. A fish has very thin gills through which the blood flows. The fish takes water into its mouth and sends it backward over the gills and out through the gill slits on the sides of its neck. As the water passes over the gills, the oxygen from the water passes into the blood, and the carbon dioxid from the blood is given off into the water. A fish cannot live in boiled water, because when water is boiled, the air is driven out. It cannot live in the air, because when taken out of the water, its gills stick together, and the oxygen cannot get in among the gills to pass into the blood.

The frog, instead of making a vacuum in his chest and thus causing the air to pass into the lungs, takes air into the mouth, and by drawing in the skin under its chin, forces the air downward. Watch a frog breathing, and note how the throat works out and in. When under water, the frog gives off carbon dioxid and absorbs oxygen through its thin, moist skin. It may interest you to know that a frog does not drink water, but absorbs this also through the skin, the water passing into the blood which flows in the capillaries of the skin.

A bird has no diaphragm and the lungs run far back in the body. In many birds branches from the lungs go out even into the hollow bones.

HYGIENE

Five points connected with the hygiene of the respiratory system are worthy of notice. The first is in regard to the *effects of tight clothing about the body.* This interferes with the respiratory movements, and is a great evil, for it leads to shallow breathing, in which the air passes into and out of the trachea and larger bronchial tubes without sending much oxygen into the air sacs or taking much carbon dioxid out of them.

The second point is in regard to the *danger of breathing dust.* Large numbers of people die every year from consumption, pneumonia, diphtheria, and grip, and many more suffer from catarrh and other diseases of the respiratory organs.

All these diseases are carried by germs, and persons who breathe dusty air suffer greatly from them. The reason for this is that the dust particles cut and wound the air passages, and the germs are able to gain an entrance into the tissues at these points and set up their growth. Every effort should be made, therefore, to keep from breathing dust. Streets should be kept sprinkled, and when floors are swept, as little dust as possible should be raised. Dust should be wiped from walls and furniture with a damp cloth, and not stirred up into the air. Everything possible should be done to prevent the inhalation of dust, for most respiratory diseases are germ diseases, and the germs are frequently able to attack these parts because of the wounds made by particles of dust.

The third point which we wish to mention is the *value of deep breathing exercises.*[1] It is an excellent plan for every one, several times a day, to stand erect, as directed on page 71, fill his lungs to their utmost capacity, hold the air for a

[1] It is well to know that breathing exercises are very injurious to any one who is suffering from consumption.

few moments, and then slowly and steadily exhale it. This takes the oxygen deep into the lungs, brings out the carbon dioxid, and quickens the heart beat, thus starting the blood more swiftly through the whole body.

Outdoors, in the fresh air, is the best place to take these breathing exercises, and you can practice them as you walk to and from school. But a better time to practice them is when you have become tired from sitting over some task for a considerable time. Then you will find that it will rest and refresh you to go to a window, open it, and take several deep breaths of fresh air. In school, when every one has been sitting quietly until the respiration has become shallow and the heart beat slow, it is very beneficial to throw the windows wide open and have everybody stand up and take several deep breaths, along with some stretching exercises to relieve the cramped muscles. A couple of minutes spent in this way takes very little time, and sets everybody to work again with renewed vigor. You must take care, however, not to practice breathing exercises so vigorously that you make yourself dizzy, or you may do yourself more harm than good.

The fourth point to which we would call your attention is in regard to the *use of alcohol.* Users of alcohol are particularly liable to attacks of pneumonia, catarrh of the pharynx, larynx, and bronchial tubes, and to other respiratory diseases. The chief reason for this seems to be that alcohol weakens the power of the body to kill germs. We shall take up this whole subject in a later chapter, but you should know now that when pneumonia or grip is abroad, and every one is trying to keep himself in the best possible health so that he will be able to kill any germs that get into his body, drinking alcohol, even in small amounts, will greatly lessen the power of the body to resist germs.

The last point which we would ask you to note in connec-

tion with the hygiene of the respiratory organs is *the effect of cigarette smoking* on the lungs and on the health of the whole body. Users of cigarettes very commonly inhale the smoke. This smoke is irritating to the air passages and has a very injurious effect on the lungs. In addition to the poisonous substance that is in the tobacco, cigarette smoke contains a gas called carbon monoxid (page 149, footnote). Both the poison of the tobacco and the carbon monoxid pass into the blood in the capillaries of the lungs and injure the cells of the body.

THE VOICE

The Cartilages of the Larynx. The walls of the larynx are mainly composed of two great cartilages, the *thyroid* and the *cricoid*. The thyroid cartilage is the "Adam's apple" which you can feel in the front of your throat. It is somewhat V-shaped, with the opening behind. Set upon end a partially opened book, and it will represent fairly well the shape of the thyroid cartilage.

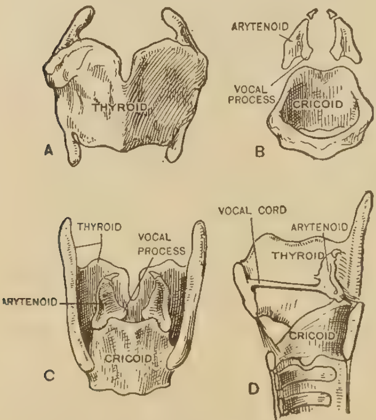


FIG. 85. The cartilages of the larynx. *A* and *B* show the cartilages as seen from the front. *C* is the back of the cartilages in their natural position. *D* is a longitudinal section of the larynx showing the vocal cord stretched from the thyroid cartilage in front to the vocal process of the arytenoid cartilage at the back.

The cricoid cartilage forms a complete ring, but it is much narrower in front than behind (Fig. 85 *B*). In front, the cricoid lies in the larynx wall below the thyroid (Fig. 85 *D*), but at the back its

wide part stands up between the two wings of the thyroid and forms the back wall of the larynx (Fig. 85 *C*).

On top of the cricoid, at the back, stand up the two little *arytenoid* cartilages. Each one is loosely hinged at its base, so that to a certain extent it can slide outward toward the side wall of the larynx or inward toward the other arytenoid. It has on the inner side of the base a small projection called the *vocal process* (Fig. 85 *B*), to which the back end of the vocal cord is attached.

The Vocal Cords. The vocal cords are insignificant little bands of connective tissue that run along the side walls of

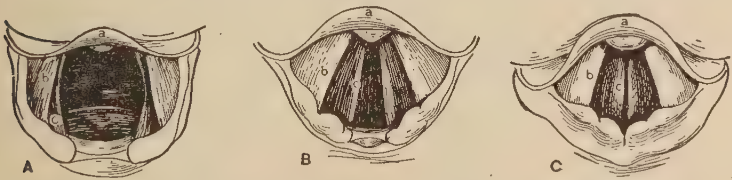


FIG. 86. The mouth of the larynx viewed from above. *A* shows the position of the vocal cords (*c*) in deep breathing; *B* is their position in ordinary breathing; and *C* shows them brought together for speaking or singing. *a* is the epiglottis.

the larynx from the front to the back. They are attached to the thyroid cartilage in front and to the vocal processes of the arytenoid cartilages at the back. They are buried in the mucous membrane that lines the larynx, and are therefore attached to the side wall of the larynx by one edge. If you will gather up and draw out a fold of skin on the back of the hand, you will have something that in a way represents a vocal cord.

The Vocal Cords in Action. In ordinary breathing the vocal cords lie close to the walls of the larynx and are not affected by the air as it passes out of and into the lungs. In talking or singing the cords are drawn out from the walls and stretched

across the opening of the larynx, until there is only a narrow slit between the cords. The air passing out over the tightly stretched cords causes them to vibrate and produce the sound of the voice. To make a gentle sound, a slight current of air is passed over the vocal cords. To make a loud sound a heavy current of air is sent out.

How the Vocal Cords are thrown into and out of Action. The vocal cords are thrown into and out of action by mus-

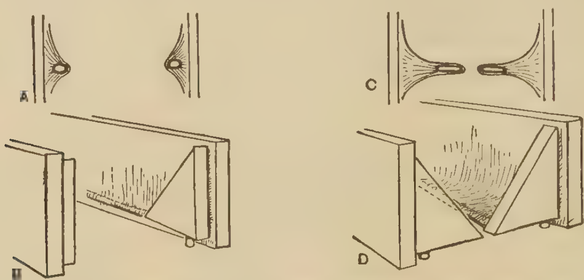


FIG. 87. Diagram illustrating how the vocal cords are brought into action. When the points of the arytenoid cartilages (represented by the gates in the diagram) to which the cords are attached are turned forward, the cords lie close to the wall. When the cartilages swing out, as in *D*, the cords are drawn out from the walls, as in *C*.

cles that are attached to the arytenoid cartilages. When a sound is to be produced, the arytenoid cartilages are made to slide inward toward each other and are rotated (Fig. 87 *D*), so that they draw the vocal cords out from the walls (Fig. 87 *C*). The cords are thrown out of action by sliding the arytenoid cartilages outward and rotating them so that the vocal processes point forward (Fig. 87 *B*). This allows the cords to lie close to the larynx walls (Fig. 87 *A*).

The Pitch of the Voice. The heavy strings of a guitar or of a violin give a low tone, and the light strings give a high tone. In strings of the same weight, a tight string gives a

higher tone than a loose string, and a short string a higher tone than a long string, as you can tell by tightening the strings on a stringed instrument, and changing their lengths by fingering them. The pitch of the sound depends, therefore, on the *weight*, the *length*, and the *tightness* of the string.

Persons who have long and heavy vocal cords have low voices, and persons with short and light vocal cords have high voices. The larynx of a man is larger than the larynx of a woman, his vocal cords are larger and longer, and his voice has, therefore, a lower pitch.[1]

Change of pitch in the voice is brought about by the muscles of the larynx tightening and loosening the vocal cords. When a low tone is to be produced, the cords are loosened. When a high tone is to be produced, the cords are tightened. When one thinks how many notes a singer makes in a few minutes, tightening the vocal cords just enough to give the right pitch to each one, he realizes how rapidly and accurately the muscles of the larynx must work.

Summary. Respiration is necessary to take in oxygen and give off carbon dioxid. The lungs are in the thoracic cavity. This cavity is enlarged and air drawn into the lungs by lifting up the framework of the chest and by pulling down the diaphragm.

The air passes through the nasal passages and pharynx, enters the larynx, and goes down the trachea and its branches into the air sacs of the lungs. In the air sacs it gives up its oxygen to the blood and takes up carbon dioxid and water from the blood. The air passages are lined with

[1] When male and female voices sing in unison, the male voices are an octave lower than the female. At the time when a boy's voice changes, the larynx suddenly grows very much larger, and the vocal cords are lengthened. While the voice is changing it should not be given any severe use.

mucous membrane, and in most parts the walls are covered with cilia. The mucus catches dust, and the cilia sweep it out of the air passages.

Tight clothing about the body interferes with breathing; many diseases of the respiratory organs come from breathing dust; deep breathing exercises are very valuable; alcohol brings on lung diseases; and cigarette smoking injures the lungs.

The cartilages of the larynx are the thyroid, cricoid, and arytenoids. The vocal cords are attached to the thyroid in front and to the arytenoids behind. In speaking or singing, the vocal cords are thrown out from the wall, and the voice is produced by passing a current of air over the cords. The pitch of the voice depends on the weight, length, and tightness of the cord.

QUESTIONS

What is inspiration? expiration? respiration? By observing the breathing of some person who does not know what you are doing, find out how many times he breathes in a minute.

What is the object of respiration? Why is oxygen necessary to the body? Of what are the lungs chiefly composed? How much blood goes to the lungs? What is the covering of a lung called? Into how many parts is the thoracic cavity divided? What is in the side chambers of the thoracic cavity? the middle chamber? Make a drawing showing the location of a pleura.

In what two ways is the chest enlarged? How is the air forced out of the lungs? Trace the air down into the lungs, naming the different parts of the air passages. Describe the nasal passages. How does the air get from the nasal chambers into the mouth?

Describe the pharynx. What separates the pharynx from the mouth? What is its use? Where are the tonsils? How are food and water kept from falling into the larynx?

Describe the branching of the trachea. What are the branches of

the trachea called? How are the trachea and bronchial tubes kept open? Describe an air sac. In what length of time does all the blood in the body pass through the lungs? What passes from the air into the blood? from the blood into the air?

With what is the respiratory tract lined? How is it kept moist? What parts of the respiratory tract are covered with cilia? What is the use of the mucus? of the cilia? What are the nasal passages especially fitted to do? Why is mouth breathing harmful?

How does an insect breathe? a fish? Why cannot a fish live in boiled water? in the air? How does the frog take air into its lungs? How does it respire while under water? How does a frog take water into its body? What is peculiar about a bird's lungs?

Why is tight clothing harmful? Name five germ diseases of the respiratory organs. How does dust cause these diseases? What measures are useful in keeping down dust?

What effect have deep breathing exercises on the heart beat and circulation? Where should such exercises be taken? when? To what respiratory diseases are users of alcohol particularly liable?

Name the two large cartilages in the larynx. Describe the thyroid cartilage; the cricoid. Where are the arytenoid cartilages? How can they be moved? Describe the vocal cords. To what are they attached at the front? at the back? along the edge?

What is the position of the vocal cords in ordinary breathing? in talking or singing? How is the voice produced? How is a gentle sound produced? a loud sound? How are the vocal cords thrown into action? out of action?

Upon what does the pitch of a sound depend? What kind of vocal cords have persons with low voices? persons with high voices? Why has a man's voice a lower pitch than a woman's voice? How is the pitch of the voice changed?

When a bucket is lowered in water, what causes the water to rush into it? We live at the bottom of an ocean of air. What causes the air to be drawn into the lungs when the chest cavity is enlarged?

CHAPTER XIII

VENTILATION

Of all the evils that befell man when he came to live within walls and doors, the lack of fresh air is the greatest. By its own activity, the body is constantly rendering great quantities of air unfit for use, and the necessity of securing a fresh supply is always upon us. As long as man dwelt in the great outdoors, all that was necessary was for the lungs to expel the stale air and it was carried away. But indoors the air is imprisoned and is often breathed again and again. In this chapter the problem of securing a supply of fresh air will be considered.

The Air. The air consists of about four fifths nitrogen and one fifth oxygen, with small amounts of several other gases which vary at different times and places. Among the gases that exist in small quantities in the air is carbon dioxid. The nitrogen is not used in the body, but passes into and out of the lungs unchanged.

The Supply of Oxygen. Twenty-one per cent of the air is oxygen. It is absolutely necessary for life, but under ordinary circumstances the air and the blood always contain enough oxygen for the cells. As long as more than 10 per cent of the air is oxygen, a person lives as well as if he were breathing pure oxygen. Expired air still contains 15 per cent of oxygen, so there would be no lack of oxygen in the body, even though the air were breathed twice.

Carbon Dioxid. Air contains a little less than 4 parts in 10,000 of carbon dioxid. Expired air contains about 430

parts in 10,000 of carbon dioxid. Stating it in another way, ordinary air is .04 per cent carbon dioxid, and expired air is 4.3 per cent carbon dioxid. The air that leaves the lungs, therefore, contains more than a hundred times as much carbon dioxid as the air that enters them. Under extreme conditions enough carbon dioxid may collect in crowded buildings to be harmful, but it is now believed that the amounts found in rooms that are ordinarily well ventilated are without harmful effects.[1] An oil stove or a gas stove that is not connected with a chimney gives off great quantities of carbon dioxid and is very injurious to the health.

Three Important Points in Ventilation. The whole subject of ventilation is not well understood, but the following points are known to be important:

The humidity of the air. Dry air evaporates the perspiration from the skin very rapidly, which gives a sensation of chilliness. Living in such an atmosphere also causes irritation of the eyes, nose, and throat, and a tendency to restlessness and nervousness. When the occupants of a room feel cold with the thermometer at 68 degrees, moisture should be added to the air (page 356).

In moist atmospheres the perspiration evaporates very slowly from the skin and the excess body heat is not removed. Drowsiness, overheating, and headache are apt to follow sitting in an atmosphere of this kind. Water vapor is given off from the lungs, and the atmosphere of crowded rooms is usually heavily laden with moisture.

Motion in the air. When the air is still, a blanket of moist

[1] The "choke damp" of coal mines is carbon dioxid, and this gas sometimes collects in dangerous quantities in silos and in wells. By lowering a lighted lantern its presence in a silo or well can be detected. The flame will die out if dangerous quantities of carbon dioxid are present.

air forms about the body, which in warm rooms quickly causes overheating. One of the important points in ventilation, especially in hot, moist atmospheres, is that air currents be set up that will blow away this wet air blanket and allow the body heat to be removed.

The temperature of the air. The proper temperature for indoor air depends on its humidity and on the amount of motion in it. When the air of a room is very dry the occupants will be uncomfortable unless the temperature is raised to 75 degrees. When the air is quiet and very moist, overheating will follow if the temperature rises above 65 degrees. When the air is properly humidified and has gentle air currents in it, the thermometer should stand at about 68 degrees.

Amount of Fresh Air Needed. According to accepted standards of ventilation, a man must have 3000 cubic feet of fresh air every hour. If he is working, he will need twice this amount. An eight-year-old boy needs one half as much as a man.

Usually it is not possible to change the air of a room more than five times an hour without causing drafts. Changing it five times an hour, each person must have 600 cubic feet of air space in a room to get his 3000 cubic feet of fresh air. Public buildings, therefore, should have 600 cubic feet of air space for each person, and in the living and sleeping rooms of private dwellings each member of the family should have 1000 cubic feet of space. Of course, even with this much space, the air will become bad unless there is some way of constantly changing it.

Principles of Ventilation. A room will hold only a certain amount of air, and if fresh air is brought in, part of the air already in the room must pass out. In any system of venti-

lation there must, therefore, be an opening through which the air can enter the room, and an opening through which it can escape. The cold air in a room sinks to the floor and the warm air rises to the top of the room. The opening by which the air is drawn off from the room should, therefore, be near the floor.

In ordinary buildings some air finds its way through crevices around windows and doors and through the floors. Opening and closing doors, and persons passing in and out of a room, also create a circulation of the air. Air may pass both out and in through the same opening, as you can show by the following experiment:

Hold a lighted candle near the top of an open doorway. The candle flame will be blown to one side, showing that a current of air is passing in or out through the top of the doorway. Now hold the candle in the doorway close to the floor. The air current here will usually be found to be passing in a direction opposite to the direction of the current of air in the top of the doorway. By holding the candle at different heights, find a stationary layer of air lying between two layers of air that are moving in opposite directions. Open or close some other door of the room and note the effect on the candle flame. Have some one walk through the doorway past the flame and note the effect.

Ventilating Public Buildings. In many public buildings it is impossible to have satisfactory ventilation, because the builders did not provide any special arrangements for drawing off the used air and for sending in a supply of fresh air. Windows were put in houses, not to be used as ventilators, but to admit light, and it is very difficult to use them as ventilators without causing drafts. In schoolhouses, churches, theaters, and other buildings, where many people collect, some way of forcing in fresh air and of drawing off the air which has been used, should be provided. Unless this is done, it is

almost impossible in cold weather to change the air rapidly enough to prevent carbon dioxid from accumulating in the building.

Heating Systems and Ventilation. Heating with a hot-air furnace[1] constantly sends a supply of fresh but very dry air into the room. A fireplace gives considerable ventila-

FIG. 88. How a fireplace helps to ventilate a room. A current of air passes up the chimney, and this causes the fresh air to be drawn into the room.

tion by causing a draft of air up the chimney. Stoves give some ventilation in the same way, but not so much as an open fire. Radiators heated by hot water and steam give no ventilation.

Avoiding Drafts. One great problem connected with ventilation is how to get the fresh air into the room without causing cold drafts. One of the most satisfactory ways of doing this is to have warm air sent in by the heating system. Some

[1] Some cheap iron furnaces, when they become red hot, allow gas from the coal to pass through them. Breathing this gas is exceedingly unhealthful.

very useful devices for ventilating are made, by which air is drawn in behind a fireplace or into a jacket around a stove and warmed before it comes into the room. A board set under a window sash allows the air to come in between the two sashes and go upward without causing a draft on those sitting in the room. Muslin fronts, which admit air without causing drafts, have long been used in poultry houses, and cloth window screens are now in use as ventilators in many schools.

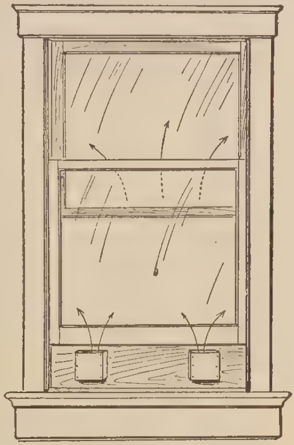


FIG. 89. Ventilating by placing a board under a window.

Even when buildings have been constructed with no ventilating system, it is possible to do much to secure fresh air without causing harmful drafts. Several windows may each be opened a little, when to open one wide would cause great trouble. Schoolrooms and churches should be filled with fresh air while they are empty. At noon and during recesses schoolroom windows can be opened and a great deal done in a very short time toward getting out the stale air.

Importance of ventilating Sleeping Rooms. A great deal of time is spent in the atmosphere of the sleeping room, and at night the air of sleeping rooms is not set in motion by the opening and closing of doors and by persons passing out and in. For these reasons the ventilation of the room where you sleep deserves special attention.

If your sleeping room is not ventilated in some other way, you should open one or more windows each night. If the windows are so arranged that they cannot be opened without

causing a draft over the bed, fit boards under the sashes, or get fresh air in some other way. Do not sleep in a closed room breathing again and again the stale air that has come off from your own lungs, and do not be afraid to admit the night air to your room, for the same atmosphere that surrounds houses during the day surrounds them at night.

Outdoor Sleeping. Every year more and more people are sleeping outdoors. It was long ago noticed that people who lived much in the open air were not troubled with consumption as were those who lived indoors. Then it was found that sleeping outdoors often helped to cure consumption. People began to wonder why anything that helped to cure sickness might not also help to keep them from getting sick, so more and more of them are building upper porches and other places where they can conveniently sleep in the open air.

It is probable that the benefits of outdoor sleeping come from spending the long time when one is in bed in an atmosphere that is fresh, cool, and constantly in motion. With this amount of time spent in the pure outdoor air, the body becomes so well and strong that it can kill off the disease germs that get into it. A well-ventilated house helps to preserve the health; walking and other exercises that require spending time in the open air are also healthful; but outdoor sleepers think their way of obtaining fresh air is the best of all, because in this way most of them spend more time in the outdoor air than they could possibly do in any other way.

Summary. The lack of fresh air is the greatest evil that accompanies indoor life. Oxygen and carbon dioxid are the important gases of the air from the standpoint of the health,

but the important points in ventilation are the humidity, motion, and temperature of the air. Each person should have 600 cubic feet of room space and 3000 cubic feet of fresh air per hour. It is especially important that the sleeping room be well ventilated, because much time is passed in the atmosphere of this room. Outdoor sleeping is a healthful practice which is probably beneficial because it furnishes the sleeper with plenty of fresh air.

QUESTIONS

Of what two gases is the air chiefly composed? Name one other gas that is found in small quantities in the air. What per cent of the air is oxygen? What per cent of expired air is oxygen? What per cent of carbon dioxid is in ordinary air? in expired air?

Name three important points in ventilation. How does dry air cool the body? What bad effects has dry air on the health? What effects follow sitting in a hot, moist atmosphere? Why is motion in the air desirable? Discuss the question of the proper temperature of the air.

How much fresh air is needed by a man when he is at rest? by a working man? by a boy? In public buildings, how much space should there be for each person? in sleeping rooms?

In ventilating, why should the opening by which the air passes out be near the floor? What is necessary for the satisfactory ventilation of crowded public buildings? What systems of heating ventilate a room? What systems give no ventilation? Explain how a fireplace or stove brings fresh air into a room. Give some ways of avoiding drafts in ventilation. What should be done while schoolrooms and churches are empty? Why should sleeping rooms be especially well ventilated? Is night air unhealthful? From what do the benefits of outdoor sleeping probably come?

CHAPTER XIV

THE KIDNEYS AND THE BODY WASTES

SOMETIMES the body is well; sometimes it becomes ill. Why is it strong and abounding in health at one time and at another time weak and ill? Usually not because it lacks food or oxygen, or because it is too hot or too cold, but because *there are poisons in the body that injure the cells.*

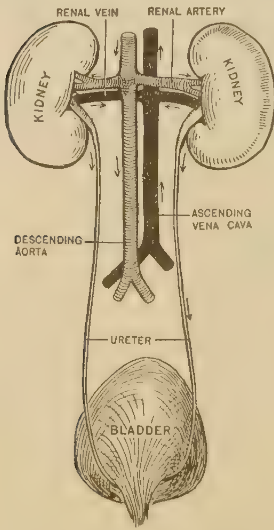


FIG. 90. The kidneys and the bladder as seen from behind.

Sometimes the poisons that cause sickness are produced by disease germs (page 285). Frequently they come from our own cells. Our bodies constantly produce carbon dioxid and poisonous protein wastes (urea and uric acid),[1] and without organs for throwing off these substances, life for us would not be possible for even an hour. We have already learned how the carbon dioxid is excreted from the body. In this chapter we shall study the kidneys, — the organs that remove the uric acid and urea from the blood.

The Kidneys. The kidneys are two bean-shaped organs. They are fastened to the back wall of the

[1] There are other protein wastes besides the urea and uric acid, but for the sake of convenience the others will be disregarded here.

abdominal cavity, one on either side of the spinal column. Stored around the kidneys are great quantities of fat. *The function of the kidneys is to excrete urea, uric acid, and water.* As the lungs purify the blood by removing from it carbon dioxid, so the kidneys purify the blood by taking out of it urea and uric acid.

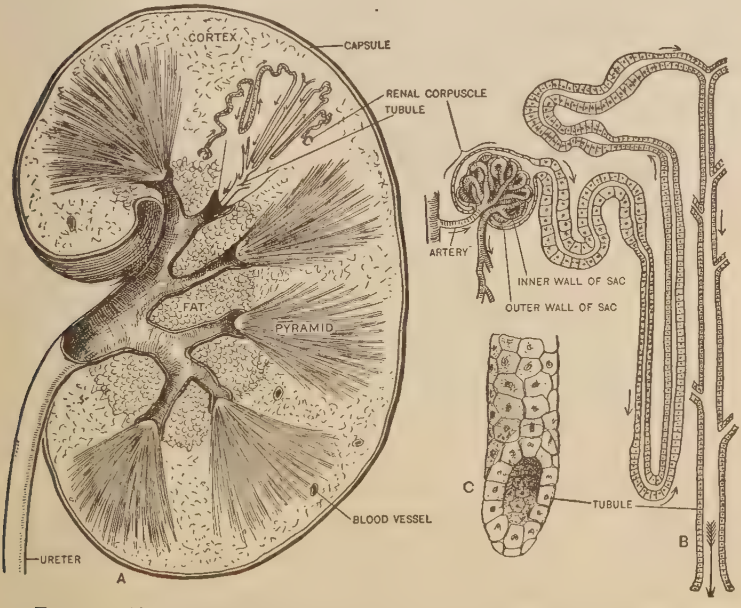


FIG. 91. *A* is a longitudinal section of a kidney, showing how the kidney tubules empty into the branches of the ureter. *B* is a kidney tubule enlarged to show the corpuscle at its upper end, and the long, winding course the tubule follows before it empties into the ureter. *C* is a small portion of a tubule, showing how the walls of the tubule are built of cells.

The Tubules of the Kidneys. The kidneys are composed chiefly of an enormous number of very fine winding tubes (*tubules*). The tubules rise in little sacs (Fig. 91 *B*) and flow

together, forming larger tubules. These larger tubules all run to the inner side of the kidney, where they empty into the branches of the *ureter* (Fig. 91 *A*).

The Renal Corpuscles. The corpuscle on the end of a kidney tubule consists of *a double-walled sac* and *a tuft of blood vessels.* The structure of a corpuscle is most easily learned by studying its development.

When the kidney is being formed in a very young animal, the kidney cells arrange themselves so as to form tubes

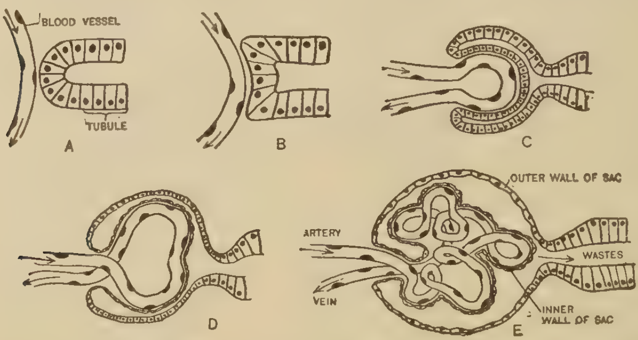


FIG. 92. The development of a renal corpuscle. The corpuscle is formed by a blood vessel pushing in the end of a kidney tubule. (After Bailey.)

(Fig. 91 *C*). A small blood vessel grows up close against the end of a tube (Fig. 92 *A*) and begins to push it in (Fig. 92 *B*). The end of the tube then broadens out and forms a small round sac, which grows up around the blood vessel (Fig. 92 *C*). Meanwhile, the blood vessel twists about and divides up into capillaries, and continues pushing in the wall of the sac (Fig. 92 *D* and *E*), until at last the corpuscle consists of a bunch of little blood vessels buried in a narrow-mouthed pocket in the end of the sac. This pocket almost fills the sac (Fig. 91 *B*).

How the Wastes are excreted from the Kidneys. When the blood is flowing through the capillaries in a renal corpuscle, the wastes escape through the capillary walls. They then pass on *through the inner walls of the sac* into the tubule, and flow down the tubule to the ureter. Also, blood capillaries are abundant all through the kidneys, and along the course of the tubules, wastes from the blood pass into the tubules *through the tubule walls.* Drop by drop the millions of kidney tubules separate the wastes from the blood and empty them into the ureters, which carry the wastes to the *bladder.*[1]

Alcohol and the Kidneys. More commonly, probably, than any other organs of the body, the kidneys become diseased from alcohol drinking. The cells in the corpuscles and tubules of the kidneys should allow the wastes to pass through them, and at the same time they should hold back the food that is dissolved in the blood. Alcohol may cause the kidney cells to become diseased and to allow the foods to escape with the wastes. Sometimes the cells suffer from fatty degeneration, and still more commonly the connective tissue in the kidney increases greatly (page 102) and strangles the cells of the tubules. In Bright's disease, which is much more common among alcohol drinkers than among abstainers, whole tubules die and the protein foods are allowed to escape with the wastes.

Summary. Ill health is often the result of poisoning the cells. The kidneys are organs for removing the poisonous protein wastes and water from the body. A kidney is composed of many fine tubules, each of which ends

[1] The amount of water excreted by the kidneys depends, of course, on the amount of liquid taken into the body and on the amount of water lost by perspiration. On an average, it is a little over three pints per day for an adult man.

in a renal corpuscle. A tuft of blood capillaries is buried in each of the corpuscles and the wastes pass out from the blood into the tubules and down to the ureters. Alcohol causes kidney trouble, Bright's disease being very common among drinkers.

QUESTIONS

To what is ill health frequently due? Where do these poisons come from? Locate the kidneys. What is deposited around them? What is their function?

Of what is a kidney chiefly composed? Describe the course of the tubule. In what does a tubule rise ? Describe the development and structure of a renal corpuscle. How do the wastes get from the blood into the tubules?

What should the cells of the kidney tubules do with the wastes and with the foods? What two diseased conditions of the kidneys does alcohol cause? What disease of the kidneys is common among drinkers?

CHAPTER XV

THE SKIN AND THE BODY HEAT

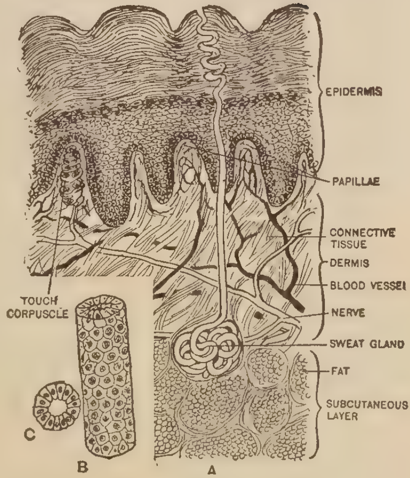


FIG. 93. A section of the skin. *B* is a small portion of a sweat gland, and *C* is a cross-section of a sweat gland enlarged to show that these glands are hollow tubes with walls composed of cells.

The Functions of the Skin. The skin has four functions. *It forms a protective covering for the body*, which keeps the more delicate tissues from being injured, and prevents disease germs from getting in among them. *It is an organ of feeling*, for most of the nerves of touch end in the skin. *It regulates the heat of the body*, permitting the body to cool off when it becomes too warm, and keeping in the heat when the body becomes cold. Its other function is *to assist the lungs and kidneys in excreting water*[1] *from the body.* The skin has two layers, the *epidermis* and the *dermis*.

[1] The lungs, kidneys, and skin give off so much water that we are compelled to drink liquids to give the body a sufficient supply of water. You should understand, therefore, that when the skin excretes water, the object is to cool the body and not to get rid of the water.

FIG. 94. A section of the epidermis. The epidermis grows by the division of the lower cells. Its outer cells dry and scale off. A papilla containing a touch corpuscle is shown. The skin pigment is in the lower cells of the epidermis.

Thickening of the Epidermis. The epidermis is the protective layer of the skin, and wherever unusual pressure comes on the skin, as on the soles of the feet or on the palms, the epidermal cells multiply very rapidly and cause a great thickening of the outer layer of the epidermis. When constant pressure falls on a small area of epidermis, as sometimes happens when a tight shoe is worn, a corn, or little mound of epidermal cells, is built up. This can be relieved only by removing the pressure that caused the growth. It is much easier to prevent corns than it is to cure them, and only properly fitting shoes should be worn.[1] A wart is a place where the epidermal cells grow and multiply more than is natural, but the cause of warts is not known. In cancer, either the epidermal cells or the connective tissue cells increase enormously and feed on the other body tissues.

The Color of the Skin. The color of the skin is due to pigment in the cells of the lower layers of the epidermis. The outer epidermal layers are partially transparent, and we look through these and see the coloring matter in the lower cells. Expos-

[1] It is estimated that 58 per cent of Americans have corns, ingrowing nails, the bones of the feet bent out of shape, or other foot troubles. The question of properly fitting shoes is, therefore, one of considerable importance.

ure to the sun or wind causes the coloring matter to become more abundant in the skin, and the skin, as we say, becomes tanned. A freckle is a spot in the epidermis where the pigment is especially abundant. It is probable that the use of the skin pigment is to protect the nerves and other delicate structures beneath the epidermis from the light of the sun.

The Dermis and the Subcutaneous Layer. The second layer of the skin is the dermis. It is composed of connective tissue in which there are blood vessels, lymphatic vessels, and nerves. The upper surface of the dermis is thrown into *papillæ* that stand up like little mountain peaks under the epidermis. Some of the papillæ contain blood vessels, and some of them contain touch corpuscles. In the lower part of the dermis considerable fat is stored The *subcutaneous layer* lies under the dermis. It is a layer of loose connective tissue in which large quantities of fat are found.

FIG. 95. The surface of the skin of the finger-tip, magnified to show the mouths of the sweat glands. In some parts of the skin the papillæ are arranged in rows, giving the surface of the skin a ridged appearance.

Sweat Glands. With a magnifying glass small pores can be seen in the skin, in some portions of the body as many as twenty-five hundred to the square inch. They are the mouths of *sweat glands*, which are little tubes composed of epidermal cells (Fig. 93). A sweat gland runs down through the epidermis and ends in a coil in the lower part of the dermis, or in the subcutaneous layer.

The Function of the Sweat Glands. *The function of the sweat glands is to cool the body by pouring out perspiration on the skin.* Around the lower part of a sweat gland are many fine blood capillaries

from which an abundant supply of lymph escapes. The water of the lymph passes on through the walls of the sweat gland into the opening in the center of the gland, and flows out on the skin. A little perspiration passes out through the sweat glands at all times, but usually the amount is so small that it passes off into the air as vapor without being noticed. On a hot day, however, or when the body becomes hot from exercise, the sweat glands work so rapidly that the water accumulates on the skin.

How the Body is cooled by the Perspiration. The body is cooled by the *evaporation* of the perspiration on the skin. Pour alcohol or ether on your hand and allow it to evaporate and your hand will feel cold. This shows that a liquid in evaporating takes up heat. You can have the same fact proved to you by visiting an ice factory and seeing water frozen by the evaporation of ammonia, or by performing the following experiment:

Note the height at which the mercury stands in a thermometer. Then cover the bulb of the thermometer with cotton, and wet the cotton with ether, chloroform, gasoline, alcohol or water. Swing the thermometer through the air and then note the height of the mercury. What causes it to fall?

The Sweat Glands controlled by the Nervous System. The sweat glands are controlled by the nervous system, which causes them to work rapidly or slowly according to the heat of the body. That the sweat glands are connected with the nervous system is shown by the way embarrassment or pain may bring out the perspiration.

The Hair. A hair grows in a small, deep pocket in the skin, called the hair *follicle*. At the bottom of the follicle is the hair *papilla*. This is a little mound of connective tissue, belonging to the upper layer of the dermis. The follicle is

lined with and the hair papilla is covered over by cells which have been folded in from the epidermis. The hair rests on the papilla, and grows by the epidermal cells at the base of the hair multiplying and pushing the cells above them upward. A hair, like the epidermis, contains neither nerves nor blood vessels. In the connective tissue of the papilla, however, is a rich blood supply, which brings food to the growing cells at the base of the hair.

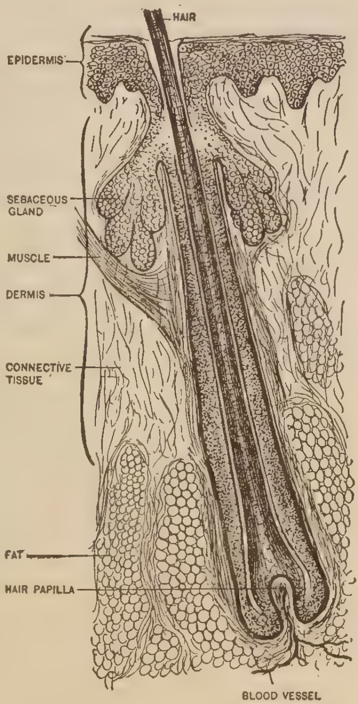


FIG. 96. A hair in its follicle.

The Sebaceous Glands and the Muscles of the Hair. Opening off from the sides of the hair follicles are the *sebaceous glands*, which manufacture a clear, odorless oil for the hair. Small muscles[1] are attached to the hair follicle in such a way that when they contract, the hair is made to stand on end. Doubtless you have seen the hairs on a cat's tail or on a dog's neck stand on end, and you probably know that in man great fright may cause these muscles to contract and make the hair stand up.

[1] The upper ends of these muscles are attached in the connective tissue just below the epidermis. Under certain conditions they contract and draw the epidermis down in little depressions, producing the condition that is called "goose-flesh."

Care of the Hair. Brushing the hair is very beneficial to it because it spreads the oil from the sebaceous glands all along the hair. Brushing the hair also causes a good circulation of blood in the scalp, thus providing the growing cells of the hair with an abundance of food and oxygen, and promptly carrying away their wastes. The hair and scalp should be washed occasionally with good soap to remove dust and oil. A little ammonia or borax in the water is useful when the hair is very oily, but if this treatment causes the hair to become dry and brittle, only soap and water should be used.

Dandruff and Baldness. It is thought that dandruff is caused by a germ that grows in the sebaceous glands and the scalp, and that this disease may be spread by hair brushes and combs. It is, therefore, safest not to use the combs and brushes that are found in public places.

Baldness is supposed usually to be caused either by dandruff or by tight hats that cut off the blood from the scalp. This is little more than a guess, however, for the subject is not well understood, and there are many cases in which neither of these explanations holds. When a hair falls out, a new hair will take its place, provided the epidermal cells that line the lower part of the hair follicle and cover the hair papilla are not destroyed. If these are destroyed, the hair will not be renewed.

The Nails. A nail is formed from the upper horny layer of the epidermis. Its growth is chiefly at the base, as you will know if you have seen a spot[1] grow forward on a nail until it reached the tip. The nail cells turn to a horny substance, and the nails have a pink appearance because the rich blood supply below can be seen through them. Where the cells are young, the blood cannot be seen so plainly through

[1] A black spot on a nail is caused by injuring the blood vessels under the nail, thus allowing the blood to flow out and form a clot.

them, and there is, therefore, a white area at the base of each nail.

When a nail is injured, or lost through accident, it will grow again, provided the bed of epidermal cells on which the nail rests and from which it grows is not destroyed. But if the "roots of the nail" are destroyed, the nail will not be replaced. The nails protect the fingers, and assist in picking up small objects.

THE BODY HEAT

A man in the cold Arctics loses much more heat than does a man living in the warm tropics. Yet the temperature of the human body all over the world is the same. A man who is violently exercising produces five or six times as much heat as a resting man produces. Yet the temperature of the human body in exercise and rest is nearly the same. In health, the human body keeps a temperature of about $98\frac{1}{2}$ degrees, varying from a little above this point to about a degree below it.

The Regulation of the Body Heat. On a cold day we can close the doors and windows of a room and with a small fire keep the temperature of the room at 70 degrees, or we can open a window and still keep the temperature of the room at 70 degrees by firing up and producing more heat. We can control the temperature of the room either through the amount of heat that is *lost*, or through the amount of heat that is *produced*. So the temperature of the human body can be kept at $98\frac{1}{2}$ degrees either by regulating *the amount of heat that escapes from the body*, or by regulating *the amount of heat produced in the body*. Both of these methods are used in our bodies.

Regulating the Escape of Heat. The skin governs the escape of heat from the body in two ways. The first way is *by regulating the amount of blood that comes out into the skin.* When the body is cold, the blood vessels of the skin contract and keep the blood in the warm internal parts of the body. When the body is hot, the vessels in the skin open up and allow a larger amount of blood to come to the outside of the body where it will be cooled.

The other method of regulating the escape of the heat is *through the sweat glands.* When the heat of the body rises, the sweat glands cool the body by pouring out perspiration on the skin. Both the vessels of the skin (page 145) and the sweat glands are governed by the nervous system, so it is the nervous system that regulates the amount of heat that escapes from the body.

Regulating the Amount of Heat produced. When the body is exposed to severe cold, much heat escapes from it, and the *cells burn an extra supply of food* to keep the body temperature up to $98\frac{1}{2}$ degrees. For this reason, men living outdoors in cold weather require great quantities of food (page 124). For the same reason, an animal that is kept outdoors in the winter needs more food than the same animal requires when it is kept in a warm stable.

The Temperature of the Body in Illness. When one is weak and ill, the body temperature sometimes falls below normal, not enough heat being produced or too much heat being lost. Sometimes the sweat glands work when they should not do so, as in the night sweats which accompany consumption and other weakening diseases. More commonly the temperature rises above $98\frac{1}{2}$ degrees, when one is said to have fever.

The Cause of Fever. In fever there is usually a greater breaking down of the tissues and a greater production of

heat than is natural. Not nearly so much heat is produced in fever, however, as in violent exercise, and the main cause of a fever is that *not enough heat is lost.* Usually the trouble is that *the sweat glands refuse to work.* The crisis or turn of a fever is usually marked by the sweat glands beginning their work, the surplus heat escaping and the fever going down from that time.[1]

Chills. In illness the skin usually is hot and flushed with blood, but sometimes the blood vessels of the skin are tightly closed and the blood is kept from coming to the outside of the body where it will be cooled. Then the skin has no warm blood, and the person has a chill and feels cold, even when the inner parts of the body are in a hot fever.

The Extremes of Body Temperature. The human body is very sensitive indeed to changes in temperature, and will die if its heat falls far below or rises much above normal. One hundred and two degrees is warm fever, and 104 degrees is a hot fever; 105 degrees, if it continues for long, is dangerous, and when a fever rises to 109 or 110 degrees, it is almost surely fatal. How far below normal the temperature can fall without fatal results depends on how long-continued the decline is, but 91 or 92 degrees will cause death in a very short time.

[1] Sometimes, in slight fevers, a hot bath, followed by an extra heavy covering of the body for a time, will start the sweat glands and lower the fever. Rubbing with alcohol quickly cools the body, because the alcohol evaporates very rapidly. Sponging with water cools the skin in the same way, but not so rapidly. Sometimes, in long-continued illness, where the temperature goes so high that there is danger of death from the fever, it is best to take the heat out of the body with ice packs or an ice-cold bath. But this (as well as rubbing with alcohol) is a shock to the nervous system, and it drives the blood inward and checks instead of starting the sweat glands. It should be used only when a physician advises it, or when the fever runs so high that it must be quickly lowered. Sponging with warm or tepid water is safer, and is often sufficient.

BATHING

Dead epidermal cells of the skin and oil from the sebaceous glands become mixed with perspiration and dust and form a considerable amount[1] of waste matter on the skin. This should be removed, or it will form a breeding place for many germs, which may get down into the hair follicles and cause pimples and other skin troubles.[2] It is important, therefore, to keep the skin clean, and to do this, soap should be used on the skin to dissolve the oily matter. For purposes of cleanliness, a moderately warm bath is best, but aside from cleansing the skin, bathing has little effect on the body except through the temperature of the water. A hot or cold bath, however, may have a decided effect on the nervous system, and through it, on the whole body.

Cold Baths. When a cold bath is taken, the blood vessels of the skin contract and send the blood to the heart, lungs, brain, and other internal parts of the body. This quickens the circulation and respiration, and causes more food to be oxidized in the body, thus producing more body heat. After the bath, the reaction (the return of the blood to the skin) usually comes, warming and reddening the skin, and giving the bather a fresh and pleasurable feeling. Rubbing the skin helps to bring on the reaction. Sometimes when the water is very cold, or the person taking the bath is weak or unaccustomed to cold baths, the reaction does not follow, and the bather is left weak and shivering. This is decidedly injurious. A person should train himself gradually to a cold bath, and should always be sure that the temperature of the water is not so low, and the time spent in the bath not so

[1] It has been estimated that a pint of epidermal cells scale off one arm and hand in a month. [2] Blackheads are hair follicles that have become stopped up.

long, that the reaction will not come promptly. Some individuals do not seem able to accustom themselves to cold baths without too great a shock to the nervous system, and these persons should bathe only in warm or tepid water.

Warm Baths. Most of the effects of a hot bath are exactly opposite to the effects of a cold bath. A hot bath opens the vessels in the skin, and draws the blood to the surface of the body and away from the muscles and the internal organs.

Time for bathing. Since a cold bath sends the blood to the brain and causes a greater amount of food to be oxidized in the body, the best time to take such a bath is in the morning, when we wish to have our energies aroused and to wake up for the work of the day. It should not be taken when one is very hot or tired. The best time for a warm bath is just before bedtime, after the work of the day is done. Persons who are troubled with insomnia (sleeplessness) sometimes find that a warm bath enables them to go to sleep. One who has been engaged in very hard exercise will find that a hot bath draws the blood away from the muscles to the skin. A warm bath should not be taken immediately before or after eating, because it draws the blood from the digestive organs. Tepid baths have no particular effect on the body, and may be taken at any time. Unless the water is cold, a swim, like other exercise, may be taken at almost any time except just before and for a time after eating.[1]

[1] It is well to know that "cramps," with which swimmers are occasionally seized, is believed to come on more frequently after eating. Just what the trouble is in cramps is not well understood. One theory is that when the diaphragm is hindered in its downward movement by a full stomach, the severe exercise of swimming and the force required to push out the body walls in the water, throws so heavy a task on the respiratory muscles that these muscles suddenly fail in their work and the breathing stops. Whether or not this theory is correct, it is probably best to follow the old rule of not taking a swim for two hours after eating.

THE HEATING OF BUILDINGS

The lower animals depend on the food which they burn in their bodies to keep up their heat, but man has learned the use of fire, and in the colder portions of the earth heats his houses. This has many advantages, but it has certain disadvantages; for when we pass from a warm house into cold winter air, there is suddenly a very great change in the amount of heat that is lost from the body.

Overheated Rooms. Many rooms both in private dwellings and in schoolhouses and other public buildings are kept too hot. This is injurious for the following reason:

In a warm room the skin is moistened with perspiration and the blood is drawn to the surface of the body. When a person passes from a warm room to the cold outside air, the perspiration on the skin continues to evaporate and take heat out of the body, and large amounts of heat are lost before the blood can be cut off from the skin. *An overheated room is injurious because on leaving it too much heat is lost from the body*, and the body is chilled. Sitting down to rest in the cold outside air when one is hot from exercising may in the same way cause the body to be chilled.

Underheated Rooms. *Cold rooms are injurious because in them the body loses too much heat* and becomes cold and chilled. Cold floors are common, and little children, especially, suffer from them. The temperature of the air at the floor of a room is often 20 degrees lower than the temperature of the air a few feet above the floor. When small children get down to play on the floor they may be passing from a warm to a cold atmosphere, and they often suffer from cold in a room that in some parts is sufficiently heated. Fires should be built on cold days in the spring and fall, or colds will follow staying in rooms that are too cool.

How chilling the Body injures it. The most common result of chilling the body is a cold. It is practically certain that a cold is a germ disease, and it is thought that allowing the body to become too cold weakens it, so that the germs can grow in it and cause the cold. One great advantage that is claimed for cold baths is that by training the vessels of the skin to close quickly they prevent the body from becoming chilled and give those who take them marked freedom from colds.

The Use of the Thermometer. In keeping a room at the proper temperature, a thermometer is a very great aid. The temperature of different parts of the room should be tested and some method of heating used that will warm all parts of the room as evenly as possible, so that some of the people in the room will not be too hot while others are too cold, or one part of the body be warm while another part of it is cold. Where rooms are heated with stoves, it will be found that a large stove gives a more steady, even heat than a small stove gives. Having one part of the body hot and another part cold is decidedly injurious, so cold floors and cold drafts are to be avoided wherever possible. From 65 to 70 degrees is the proper temperature for a room in which people are sitting, and when it is necessary to raise the temperature above 70 degrees to make a room comfortable the air is too dry and some means of adding moisture to it should be provided.

CLOTHING

Birds have feathers and most mammals have a coat of hair to retain the body heat, but in man the hair on the body is so fine and thin that it is of little use as a protection from the cold. In the colder regions of the earth, man has, therefore,

been compelled to clothe himself to keep up his body heat. *The chief physiological use of clothing is to retain the body heat.* Clothing also saves the body from wounds and bruises and protects it from the heat and light of the sun.

How Clothing retains the Body Heat. Heat passes with great difficulty through dry air, and clothing prevents the escape of the body heat chiefly through holding air in the little crevices in the cloth. The fur of animals forms a very warm body covering, and in a number of animals (including the cat, rabbit, and sheep) it has been found that on an average about 2 per cent of the fur is hair, and 98 per cent of it is air that is held in the little spaces between the hairs.

The Best Materials for Clothing. Woolen clothing is warmer than cotton or linen. Wool is therefore the best material for winter clothing, but in hot summer weather, cotton and linen clothing may be superior to woolen. Woolen clothing is warmer than the others because it has many little air spaces between the threads; in cotton and linen cloth the threads are harder, and are woven more solidly together, so that a smaller amount of air is held in the cloth.

Wool is superior to cotton and linen for winter clothing for another reason, also. It will absorb more water than either of the others, and therefore does not become dampened so quickly by the perspiration. Cold water or cold, wet clothing touching the skin takes the heat out of the body with great rapidity, and if a person clothed in cotton or linen exercises until he perspires, his clothing becomes damp; then if he rests in a cold atmosphere the heat may escape too rapidly from the body, and a cold follow.

Tight-fitting and Insufficient Clothing. Tight clothing, by interfering with the circulation of the blood, may cause coldness in some parts of the body. Cold feet are often caused

by tight shoes, which prevent the circulation of the blood. It is important that sufficient clothing be worn in cold weather to keep up the body heat; for allowing the body temperature to fall below normal at once lowers the resistance to germs and makes one more susceptible to colds, pneumonia, influenza, and other respiratory diseases. It is also important that the clothing be so distributed on the body that all parts of the body will be kept warm, and it should be loose enough to allow freedom of motion to the parts beneath it.

Other Hygienic Points connected with Clothing. *Wet clothing* takes the heat out of the body and is especially likely to cause colds. Damp feet are a common cause of sickness, and when rubbers are needed to keep the feet dry they should *always* be worn.

Wearing heavy clothing indoors has the same effect as staying in an overheated room. An overcoat should not be worn in the house, but should be put on before going outdoors, to protect the body from the sudden change to the cold of the outside air.

Heavy clothing should be worn in the spring and fall when the weather demands it. If in the spring the weather turns cool after heavy clothing has been taken off, the heavy clothing should be put on again. The clothing and the heating of buildings should be adapted to the weather, and if thin clothing is worn and fires are allowed to go out on cold days in the spring and fall, colds and sickness will follow.

Summary. The skin forms a protective covering for the body, is an organ of feeling, regulates the body heat, and excretes water. The outer layer of the skin is called the epidermis. The dermis is a layer of connective tissue under the epidermis, and the subcutaneous layer lies below the dermis. Fat is stored in this layer.

The sweat glands take water from the blood and pour it out on the skin as perspiration. By the evaporation of the perspiration the body is cooled. The sweat glands are under the control of the nervous system.

A hair grows in a hair follicle and rests on a hair papilla. It grows from the epidermal cells at its base. The sebaceous glands secrete a clear oil for the hair. Brushing and a clean scalp are beneficial to the hair. Dandruff is in all probability a germ disease and may be contracted from brushes and combs that other persons have used. Baldness is usually supposed to be due to dandruff or tight hats.

The nails grow from the epidermis. They protect the fingers and are useful in picking up small objects.

The temperature of the healthy human body is always near $98\frac{1}{2}$ degrees. The skin regulates the escape of heat from the body by controlling the amount of blood that comes to the skin and by the action of the sweat glands. The amount of heat produced in the body is regulated by the amount of food that is oxidized, extra food being burned when the body is cold.

In sickness the temperature of the body may rise too high or fall too low. The chief trouble in fever is that not enough heat is lost, the sweat glands usually failing to work. In a chill the blood is cut off from the skin.

The skin should be kept clean so that germs will not find food on it.

A cold bath is best taken in the morning and a warm bath at bedtime. Cold baths are injurious when they are not promptly followed by the reaction.

Overheated rooms cause the body to be chilled after leaving them; underheated rooms cause the body to be chilled while in them; and chilling of the body is followed by colds.

A thermometer should be used to determine whether rooms have the proper temperature.

Clothing retains the heat by holding air in its pores. Wool is a warmer material for clothing than cotton or linen. Tight-fitting clothing causes coldness of parts of the body by interfering with the circulation. Wet clothing, wearing heavy clothing indoors, and insufficient clothing during cold weather in the spring and fall are causes of sickness.

QUESTIONS

Give the four functions of the skin. Name the layers of the skin. What is a corn? What gives the color to the skin? What is a freckle?

Of what is the dermis composed? What is a papilla? Where is the subcutaneous layer? Of what is it composed, and what is deposited in it?

What are the pores in the skin? Describe a sweat gland. What is the function of the sweat glands? Where does the water of the perspiration come from? Why do we not see the perspiration on the skin at all times? How does perspiration cool the skin? What controls the sweat glands?

What is a hair follicle? a hair papilla? With what is the follicle lined and the papilla covered? When the hair grows, where do the cells multiply? From what layer of the skin is the hair formed? How does a hair get food? Where are the sebaceous glands? What is their function? What causes the hair to stand on end?

Give two reasons why brushing benefits the hair. What is the cause of dandruff? How may this disease be contracted? What causes baldness?

From what layer of the skin are the nails formed? What causes their pink color? What causes the white spot at the base of a nail? What is the function of the nails?

What is the temperature of the body in health? Give two ways by which the body heat is regulated. In what two ways does the skin regulate the escape of the heat from the body? How do the cells regulate the amount of heat produced? Why must persons living outdoors have more heat than those who live indoors?

What is fever? What is its cause? What causes a chill?

Why should the skin be kept clean? Give the effect of a cold bath on the blood vessels of the skin. Give some other effects of a cold bath. When is a cold bath injurious?

Give the effect of a warm bath on the vessels of the skin; on the distribution of the blood. When should a cold bath be taken? a warm bath? Why is a warm bath harmful immediately before or after eating? What is the effect of a tepid bath? Why should one not take a swim immediately after eating?

Why are overheated rooms injurious? underheated rooms? How does chilling the body injure it? How do cold baths prevent this? What is the proper temperature for a living room? Why is the use of the thermometer important?

What is the chief physiological use of clothing? How does clothing retain the body heat? Which is the warmest material for clothing? Why? Which material absorbs moisture best? What is the effect of tight clothing on the heat of the body? Why should the feet be kept dry? What is the effect of wearing heavy clothing indoors? At what time of the year should especial care be taken to wear sufficient clothing?

REVIEW QUESTIONS

Chapter XI. Why is the circulation of the blood necessary? Trace the blood from right auricle to right auricle. What does the blood lose and gain in the capillaries of the body? of the lungs? How is the oxygen carried in the blood? What is lymph? How is it returned to the blood? What is the function of a lymph node? Mention some common causes of injury to the heart.

Define: auricle; ventricle; artery; vein; capillary; hemoglobin; plasma; thoracic duct.

Chapter XII. What is the object of respiration? Why is oxygen necessary to the body? Why must the body get rid of its carbon dioxid? What does the air gain and lose in the lungs? Why does mouth breathing cause disease? Name five points connected with the hygiene of the respiratory organs. What kind of diseases chiefly affect these organs? How is voice produced? How are the vocal cords thrown into and out of action?

Define: pleura; diaphragm; uvula; larynx; epiglottis; bronchial tubes; mucus; cilia; thyroid; cricoid; arytenoid.

Chapter XIII. Why is ventilation necessary? How much fresh air does a person need in an hour? How much air space for each person should there be in a public building? in a private house? Explain how a fireplace or stove ventilates a room. Why is the ventilation of sleeping rooms especially important?

Chapter XIV. What is the usual cause of illness? How are the poisons that are in the body produced? What is the function of the kidneys? Explain how the wastes get from the blood into the ureters. What diseases of the kidneys are caused by alcohol?

Define: uric acid; renal corpuscle.

Chapter XV. Give four functions of the skin. Explain how the perspiration gets from the blood to the surface of the skin. Draw a diagram of a hair in its follicle. What is the temperature of the human body? How is the escape of the heat from the body controlled? When is a cold bath injurious? What is the danger from an overheated room? from a cold room? Mention some hygienic points connected with clothing.

Define: epidermis; dermis; papilla; follicle; sebaceous.

CHAPTER XVI

THE NERVOUS SYSTEM

THE first great work of the nervous system is *to cause all the parts of the body to work harmoniously together.* The second is *to act as the organ of the mind.*[1] In a former chapter we learned something of the way the body is ruled, and we have seen in a general way how the different organs are controlled and kept at work. In this chapter we shall take up in more detail the structure and the function of the nervous system.

Nerve Cells and Nerve Fibers. Nerve tissue contains nerve cells and nerve fibers. The nerve cells are much branched, are larger than most of the body cells, and have a gray color. Most of them are found in the brain[2] and spinal cord, but small groups of nerve cells called *ganglia*[3] (singular, *ganglion*) are found in various parts of the body.

[1] A simple and easy way of treating of the relation between the brain and the mind is to say that the mind is in the brain, and that it is the cells of the brain that think and feel. It may be objected, however, that we do not know where the mind is; that it can exist apart from the body altogether; and that while the function of the muscle cells is to contract, and the function of gland cells is to secrete, it is perhaps not allowable to say that the function of the brain cells is to think. The brain, however, is in some way closely associated with the mind, and we have therefore spoken of it as the organ of the mind.

[2] It is estimated that there are 1,200,000,000 cells in the gray matter on the surface of the cerebrum.

[3] There is a ganglion on the root of each spinal nerve (Fig. 103), but most of the ganglia belong to the sympathetic system (Fig. 106). They are found chiefly

A nerve fiber contains a gray central *axis cylinder*, which is a branch of the cytoplasm of a nerve cell. A nerve fiber is therefore always connected with a nerve cell and may almost be considered as a branch of a cell. A nerve cell and nerve fiber taken together are called a *neuron*. The nerve messages, which are also called *stimuli* and nerve *impulses*, travel through a fiber in the gray central axis cylinder.

Efferent and Afferent Nerve Fibers.[1] The nerve fibers in which the impulses travel *from* the brain and cord are called *efferent* fibers. They take messages to the muscles which cause the muscles to contract, and to all the glands and organs of the body, causing each to work. The fibers which carry impulses from the different parts of the body *to* the brain and cord are called *afferent fibers*.

The Nervous System as a Connector of the Body Parts. As you

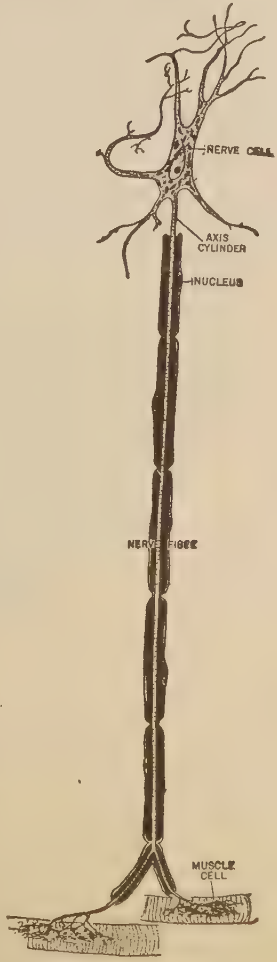


FIG. 97. A neuron.

in the internal parts of the body, and are not found in the limbs, or to any extent among the voluntary muscles. Many of them are microscopic.

[1] Efferent and afferent nerve fibers are often called motor and sensory fibers.

will understand better after studying reflex actions, a great portion of the work of the nervous system in governing the body is done by putting the different body parts into communication with each other. In a former chapter (page 23) we have spoken of the nervous system as the ruler of the body. In reality, it resembles a telephone system as much

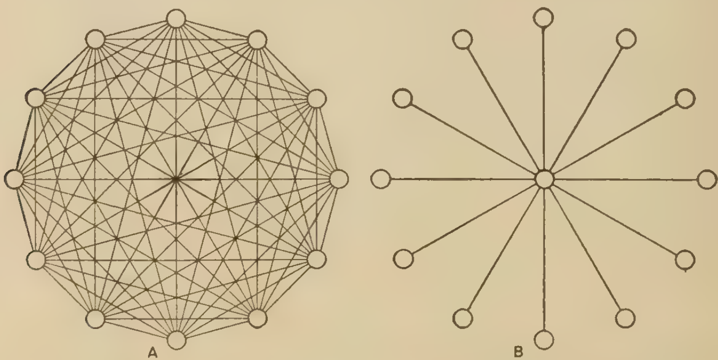


FIG. 98. *A* shows the number of wires necessary to connect twelve houses by telephone without a central office. *B* shows the number of wires necessary to connect the same number of houses through a central office. The number of nerve fibers that would be necessary to connect all parts of the body without a brain and spinal cord to act as a central office can hardly be imagined.

as it does a monarch. As on a telephone system the different houses are put into connection with each other through a central office, so the different parts of the body are connected through the brain and spinal cord. In many parts of the body each cell is supplied with a nerve fiber (Fig. 102) and the body has in it a perplexing network of nerves. By examining Figure 98, you can understand what a hopeless tangle the nervous system would become if an attempt were made to connect all the cells of the body without a brain and spinal cord to act as a central office.

THE CENTRAL NERVOUS SYSTEM

The central nervous system consists of the brain, the spinal cord, and the nerves arising from the brain and cord. Twelve pairs of nerves pass out from the brain, and thirty-one pairs from the cord, putting these nerve centers in connection with all the body parts.

The Brain. The spinal cord is only a little thicker than a lead pencil. The brain fills the whole cranial cavity. The

FIG. 99. Longitudinal section of the brain.

spinal cord of a man weighs about an ounce. The brain weighs about fifty ounces. The brain, therefore, composes by far the greatest part of the central nervous system. Its three main divisions are the cerebrum, the cerebellum, and the medulla oblongata.

The Cerebrum. The cerebrum comprises more than three fourths of the entire brain. It is divided by a deep groove in

its upper surface into a right and a left *hemisphere*. The surface of the cerebrum is thrown into a great number of folds and wrinkles called *convolutions* (Fig. 13).

A layer on the surface of the cerebrum is composed of nerve cells, and therefore has a gray color. This is the gray matter of the brain, with which the mind is associated. The inner and lower parts of the cerebrum are chiefly composed of nerve fibers.

The Fibers of the Cerebrum. A great network of fibers connects all the different parts of the cerebrum with each other. Other fibers connect the cerebrum and the cerebellum, and countless fibers run through the medulla into the spinal cord, and connect the cerebrum with the body parts below. In the medulla most of the fibers from the cerebrum cross so that the right hemisphere of the cerebrum is connected with the left side of the body, and the left hemisphere is connected with the right side of the body. If, because of injury or of apoplexy, a blood clot forms on the right side of the cerebrum, it will be the left side of the body that will be paralyzed.

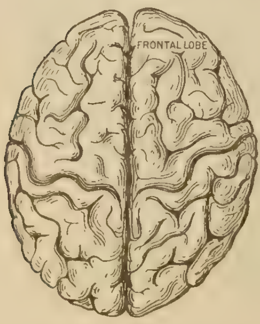


FIG. 100. The cerebrum from above, showing the hemispheres.

Functions of the Cerebrum. The cerebrum has three functions:

The cerebrum is the seat of the mind. When the cerebrum of a pigeon or of a dog is removed, life may go on, but all memory and reason are lost, and the animal is hopelessly idiotic. Removing the gray matter on the surface of the

cerebrum has the same effect on the intelligence as removing the whole cerebrum.

The cerebrum is the seat of the sensations. Nerve messages from all parts of the body come into the cerebrum and cause the sensations of light, sound, taste, smell, touch, heat, cold, hunger, fatigue, and other sensations. Without a cerebrum an animal has no mind, and without a mind there could, of course, be no knowledge of the afferent nerve impulses and no such thing as a sensation of pain, cold, hunger, or any other kind of sensation.

The cerebrum originates and sends out impulses that cause voluntary movements. When we decide to move, the cerebrum can start out impulses which cause the muscles to contract. We have, therefore, the power of voluntary movement —the power to make the muscles work when we wish them to do so.

The Cerebellum. The cerebellum lies behind and above the medulla, and is covered over by the back lobes of the cerebrum. Many nerve fibers connect the two sides of the cerebellum with each other. The cerebellum is also connected with the cerebrum, and through the medulla and cord with most of the body. The cells in the cerebellum are mainly in a layer on the surface, and the fibers in its central lobe are arranged so that they form a tree-like mass of white matter, called the *arbor vitæ* ("tree of life").

Function of the Cerebellum. There is much dispute about the function of the cerebellum, but it seems to be about as follows:

The cerebellum causes all the muscles to keep a proper amount of contraction. When the cerebellum is injured, all the muscles are relaxed, instead of keeping a certain amount of contraction as they usually do. The result is trouble in the movements, because when the cerebrum causes a muscle

to contract, the antagonistic muscle does not work in opposition and steady the motion. This causes jerky movements and movements that often go too far (page 67).

The second function of the cerebellum is *to assist in coördinating the movements of the muscles of locomotion.* When a man's cerebellum is injured, he staggers about as though he were intoxicated. His muscles are not paralyzed, but some of them contract too powerfully, some not powerfully enough, and often they fail to contract at the right moment. The cerebellum seems to cause the muscles that are used in standing, walking, and running to act in an orderly manner, and thus keeps the body from falling.

The Pons. The pons lies in the pathway between the different parts of the brain, and it is composed chiefly of fibers that connect the cerebrum, cerebellum, and medulla. There are also in the pons many fibers that connect the two sides of the cerebellum. From one side of the cerebellum the fibers pass forward to the pons, cross over in it, and turn backward into the other side of the cerebellum. The word "pons" means a bridge, and the pons is a bridge connecting all parts of the brain.

The Medulla. The medulla contains many nerve fibers that connect the higher parts of the brain with the spinal cord and the body. The greater part of the head and many of the internal organs, including the heart and lungs, are supplied by nerves that rise from the medulla. When the cerebrum is removed from an animal, the intelligence is lost, but life may go on; when the cerebellum is injured, the control of the muscles is lost; but when the medulla is injured, death comes at once because the breathing stops.

The Function of the Medulla. *The medulla conducts stimuli to and from the higher parts of the brain*, and *it acts as a reflex*

center for the parts of the body that receive nerves from it. To understand what is meant by a reflex center we must know what a reflex action is. Before taking up this subject we shall discuss the spinal cord, for like the medulla the spinal cord is a reflex center.

The Spinal Cord. The inner part of the spinal cord is composed of gray matter (cells) and the outer part of white matter (fibers). All the skin and the voluntary muscles of the body parts below the neck are supplied by the thirty-one pairs of spinal nerves, and through the sympathetic system the spinal cord is connected with the internal organs, the sweat glands, and the blood vessels.

Functions of the Spinal Cord. The spinal cord has the same two functions as the medulla. The first of these functions is *to conduct impulses to and from the brain.* The nerve impulses that come in through the spinal nerves pass up to the brain through the cord, and the nerve impulses sent out by the brain to the glands and muscles come down through the cord. For this reason, if the spinal cord be cut across, all parts of the body supplied by nerves from below the cut lose their feeling and are paralyzed. The impulses from these parts cannot get up to the brain to cause sensations of feeling, and the commands of the brain cannot get to the muscles below the cut to cause them to move. The other function of the spinal cord is *to act as a reflex center.*

Reflex Actions. *Reflex actions are actions that are caused by impulses which start in afferent nerves.* An example will give the clearest idea of a reflex.

Suppose you burn your finger by touching a candle flame (Fig. 101). The heat starts an impulse up the afferent nerve fibers. The impulse passes into the spinal cord, then into the efferent nerve, and traveling down to the muscles of the

arm, causes them to contract and jerk the hand away. An impulse also goes on up to the brain and causes a sensation of pain, but the hand is moved before the pain is felt.

An action like this is a reflex action. It differs from the action when you voluntarily move your hand in the place in which the nerve impulse starts. In the voluntary action, the brain originates and starts out the impulse. In the reflex

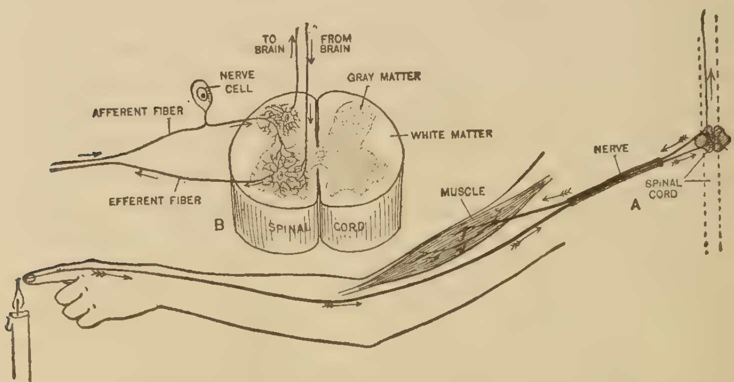


FIG. 101. Diagram illustrating reflex action. The impulse starts in the finger and passes through the spinal cord to the muscle of the arm. *B* shows the way the connections between the neurons are made in the cord.

action, the impulse starts in the outer ends of the nerves, goes into the cord, and comes back down the nerves to the muscles. In this action *the spinal cord makes the connection between the afferent and efferent neurons.*

Could a reflex be carried on without thought? Could the spinal cord carry on reflexes without the brain? If nothing disturbed the outer ends of the afferent nerves, would a reflex center ever cause movement? Think out these problems, and you will read the next paragraphs more intelligently.

The Spinal Cord as a Reflex Center. The spinal cord can carry on reflexes in a wonderful way without the aid of the brain. A shark with its head cut off, swims in a very natural manner. A turtle can walk about after it has lost its head. If a drop of weak acid or strong vinegar is put on the back of a brainless frog, the frog will wipe the acid or vinegar off with its foot. If the foot that the frog is using is held, the other foot will then be used. The spinal cord, without the brain, can carry on reflex actions for any part of the body that is supplied by the spinal nerves.

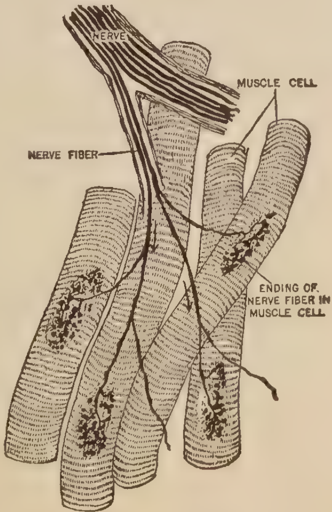


FIG. 102. The efferent nerve ending in the voluntary muscle cells. Through the nerve fibers impulses come into the muscle cells and cause them to contract.

What the Spinal Cord does in Reflexes. The spinal cord not only acts as a connector between the afferent and the efferent neurons, but it makes the *right* connections so that the proper muscles will be moved. *It also arranges and sets in order the impulses that come to it*, hurrying them on to some muscles, holding them back from others, making some of the stimuli strong and others weak, so that in a movement like the swimming of the shark, which involves almost the whole body, each muscle gets its stimulus so that it will contract at exactly the right moment and with the proper force. Yet the spinal cord has no intelligence; for a brainless frog will sit and dry up beside the water that would save its life, and

all memory is gone from an animal that has only a spinal cord.

Other Reflex Actions. Reflex centers are found not only in the cord but also in the medulla and in the lower part of the brain in front of the medulla, and to a large extent the body is governed through its reflex centers. If the eye is touched, the eyelids will close. Tickling the inside of the nose causes sneezing, and tickling the inside of the larynx causes coughing. Cold water thrown on the face causes the breath to be drawn in suddenly, while a sharp odor, as of ammonia, stops the inspiration. Water starting into the nose also checks the breath, and in diving birds, water poured across the nostrils will for a long time hinder inspiration. Heat on the skin makes the vessels relax, and cold causes them to contract. The passing of digested food into the intestine causes the pancreas to secrete its juice and the gall bladder to be emptied. Almost the entire government of the internal organs is carried on by reflexes of which we are not even conscious, but when one of these organs gets into trouble, the impulses that the afferent nerves carry up to the brain give us the sensation of pain and let us know that some of our organs need attention.

The Body Self-governing through the Reflexes. A close study of the reflexes shows that *they are all purposeful.* Even those which are carried out without intelligence or consciousness are all beneficial to the body. In studying them, one also becomes impressed with the fact that the body itself brings these reflexes about, and through them largely regulates itself. For example, when the heart beats hard and the arteries are tightly stretched with blood, it takes a forcible contraction to squeeze the blood out of the ventricles into the arteries. The pressure of the blood within the heart then

starts impulses up the afferent nerves of the lining of the heart. These pass to the medulla, and impulses which slow up the beat of the heart come down the efferent nerves. Thus the heart largely regulates itself, the high blood pres sure causing it to slow its beat. By the effects of heat and cold on the skin, the blood vessels are largely controlled, and many other parts of the body are also, to a certain extent, self-governing. We must not give too much credit to the nervous system for its wonderful wisdom in regulating the body, for usually the impulses which cause the action of the muscles and glands are not started by the nervous system at all, but by some other part of the body, and all that the nervous system does is to make the proper connections between the afferent and efferent nerves.

Acquired Reflexes. Besides these natural reflexes, there is another set of reflexes that is acquired by practice. In skating, riding a bicycle, rowing, boxing, fencing, playing a piano, and in almost any kind of activity, movements are made without thought. The eye of the piano player sees a certain note, and his finger strikes the right key. The bicycle rider feels a slight leaning of his wheel to the side, and he shifts his body so as to keep the balance. These movements have been made so often that they become reflex, and are carried out without thought.[1]

Habit. The performance of any act with which the mind is connected makes easier a further performance of that act. For instance, the fingers of the pianist move slowly and awkwardly at first, since the mind requires time to decide where

[1] The acquired reflexes are all associated with the mind, and their seat is in the outer layer of the cerebrum. When this is removed, all the acquired reflexes are lost, while the natural reflexes that are carried on by the lower parts of the brain and by the cord remain.

each finger shall be placed. But after long practice the fingers move rapidly and without thought. By practice the skilled swordsman has trained his nervous system so that without thought — so quickly that there is not time for thought — his sword follows that of his antagonist and turns aside the thrust.

As a physical habit can be formed by the repetition of an act, so mental and moral habits can be formed — habits of good work and of poor work; of honesty and dishonesty; of neatness and accuracy, and of carelessness and untidiness; habits of preparing lessons and of leaving them unprepared. All kinds of habits are formed most readily in youth, and it is seldom that, after the age of twenty-five or thirty, long-established habits are broken. Indeed, it is difficult at any time of life to break a habit that has once been thoroughly formed. The pupil who is idle in the third grade is usually an idler still in the sixth grade. The trifler in the sixth grade is usually a trifler still in the high school; and it would be almost a miracle to find a high school drone who had become a capable and industrious college student.

Just what it is in the nervous system that makes it want to keep doing the same things over again, is not known. But it is well known that what a person does in youth determines very largely what that person will both do and be in his later life. The character is largely formed by the habits, and there is much truth in the old proverb which says, "Sow an act and reap a habit; sow a habit and reap a character."

Summary. The nervous system controls the body and is the organ of the mind.

Most of the nerve cells are in the brain and spinal cord, but a few of them are in ganglia. A nerve cell and its fiber are called a neuron. Nerve fibers that carry impulses outward

are efferent fibers, and those that carry them inward are afferent fibers. The nervous system does a great part of its work by acting as a connector of the body parts. It is arranged like a telephone system in which the spinal cord and brain correspond to the central office.

The cerebrum is the largest division of the brain. It is divided into hemispheres and has many convolutions on its surface, to give room for the cells that are associated with the mind. The fibers from it cross in the medulla, so that the two hemispheres of the cerebrum are connected with opposite sides of the body. The cerebrum is the seat of the mind and of the sensations, and originates impulses that cause voluntary motion.

The cerebellum causes the muscles to keep a proper amount of contraction and coördinates the movements of the muscles of locomotion. The pons is a bridge between the different parts of the brain. The medulla connects the brain and spinal cord and gives rise to nerves that supply the head and many internal organs, including the heart and lungs. The function of the medulla is to transmit stimuli and act as a reflex center. The spinal cord gives rise to many nerves. It conducts stimuli and is a reflex center.

In a reflex action the impulse starts in an afferent nerve, passes inward to the brain or cord, and comes out again along an efferent nerve. Reflexes are carried on without thought, and through them the body is in a great measure self-regulating. Certain reflexes may be acquired by practice, and habits are easily formed. To a large extent the habits formed in youth determine what the character will be.

QUESTIONS

Give two functions of the nervous system. Where are most of the nerve cells found? What is a ganglion? an axis cylinder? a neuron?

What is an afferent nerve fiber? an efferent nerve fiber? How is an important part of the work of governing the body done by the nervous system? What is the advantage in having the nervous system arranged with a central portion through which all the body parts are connected?

What are the parts of the central nervous system? How large is the brain as compared with the spinal cord? Name the three divisions of the brain. How large is the cerebrum? How is it divided? What are the convolutions? Where is the gray matter of the cerebrum? Of what is it composed? With what is it associated? With what part of the body is the right hemisphere of the cerebrum connected? Where do the fibers from the cerebrum cross? Give three functions of the cerebrum.

What is the arbor vitæ? Give two functions of the cerebellum. What is the result of injury to the cerebellum? Where is the pons? Of what is it composed and what does it do? What part of the body is supplied with nerves from the medulla? Why does injury to the medulla cause death? Give two functions of the medulla.

Where are the fibers in the spinal cord? the cells? What two functions has the cord? What is a reflex action? Give an example of one. What is the great function of the spinal cord in a reflex action?

Mention some reflexes that can be carried on without the brain. What does the spinal cord do in these reflexes in addition to making the connections? Does it have intelligence? Where are some other reflex centers? What are some of the reflexes that are carried on by them? Give some examples of how the body regulates itself through reflexes.

What is an acquired reflex? Give examples of acquired reflexes. How are habits formed? Why is it important that correct habits be formed early in life?

CHAPTER XVII

THE NERVOUS SYSTEM (Continued)

NERVES

The Cranial Nerves. The twelve pairs of cranial nerves rise from the brain. The first pair are the nerves of smell, and the second pair are the nerves of sight. The nerves of taste and of hearing are also cranial nerves. In general, the cranial nerves supply the head, but one pair of nerves from the medulla goes to the internal organs of the body (page 216).

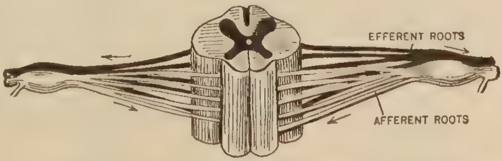


FIG. 103. The spinal cord and the roots of a pair of spinal nerves.

Spinal Nerves. Thirty-one pairs of spinal nerves pass outward from the spinal cord through openings between the vertebræ. Each spinal nerve has a ventral and dorsal set of roots. The ventral roots come from the front of the cord and the dorsal roots from the back of the cord. The ventral roots contain the efferent fibers, and the dorsal roots the afferent fibers. Outside of the spinal cord the roots unite to form one nerve, which contains both efferent and afferent fibers.

Effect of cutting and stimulating a Spinal Nerve. The afferent impulses pass into the cord through the dorsal roots of a

spinal nerve; the efferent impulses pass out of the cord through the ventral roots. What effect would it have on the part that is supplied by a spinal nerve, if the nerve were cut as in *A* (Fig. 104)? If it were cut as in *B*? as in *C*?

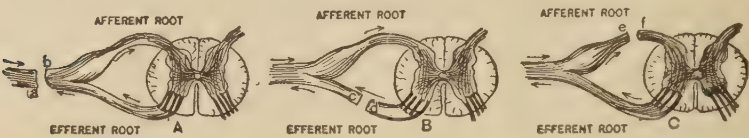


FIG. 104. *A* is a spinal nerve that has been cut; *B* is a spinal nerve, with the efferent root cut; *C* is a spinal nerve with the afferent root cut.

A nerve impulse started in the wrong direction in a nerve produces no effect. Suppose that by pinching the cut end of the nerve or by touching it with an electric wire you stimulated it and started an impulse in it. What effect would it have to stimulate the cut end at *a* (Fig. 104)? at *b*? at *c*? at *d*? at *e*? at *f*?

THE SYMPATHETIC NERVOUS SYSTEM

Nearly all the cells of the central nervous system are in the brain and spinal cord. They are collected in great centers. The cells of the sympathetic nervous system are in ganglia, which are scattered through the body. This system consists chiefly of two chains of ganglia, one on either side of the spinal column; of scattered ganglia in many of the internal organs, especially the intestine and other abdominal organs; of a great network of fibers that connect all these ganglia with each other and with the spinal cord and brain; and of the sympathetic nerves that supply various organs.

From some of the cranial nerves and from all of the spinal nerves, branches run to and from the sympathetic ganglia. Every part of the sympathetic nervous system is thus con-

nected with the central nervous system, the medulla and the sympathetic system being especially closely connected. Thus the central nervous system is able, through the sympathetic system, to reach the parts of the body that are not supplied with nerves directly from the brain and cord.

The Function of the Sympathetic System. In general *the sympathetic system controls the internal organs* (heart and blood vessels, digestive organs, kidneys, etc.) *and the sweat glands and vessels of the skin.* It controls these organs chiefly through reflex actions, yet the sympathetic system is not an independent system. It cannot do its work without the central nervous system, as you will understand when you have learned how sympathetic reflexes are carried out.

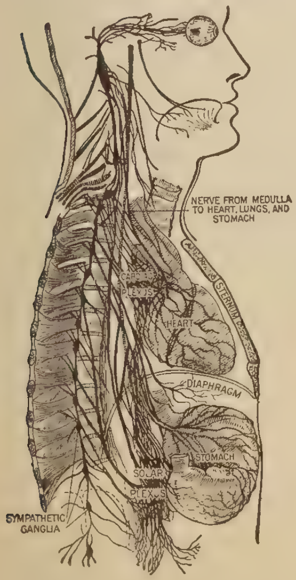


FIG. 106. Side view of the sympathetic nervous system. Note the chain of ganglia lying beside the spinal column, and the great network of fibers running to the internal organs.

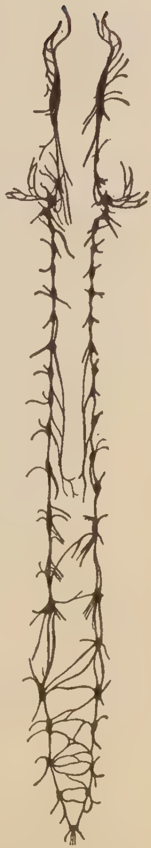


FIG. 105. The two chains of sympathetic ganglia.

Sympathetic Reflexes. A sympathetic ganglion *has not the power to turn an impulse back* and cause a reflex action, but

when the ganglion receives an afferent impulse, it sends the impulse on into the spinal cord or brain, where it is started back down an efferent nerve. The impulses go through ganglia on their way to and from the cord and brain, but *the reflex centers lie in the central system.* Although the central nervous system takes part in the sympathetic reflexes, yet we have no consciousness of these reflexes. Neither is it possible for us by a voluntary effort to influence the internal organs through the sympathetic system. This system is connected with the spinal cord and with the lower centers of the brain, and not with the higher centers of the brain, with which the mind is associated.

FIG. 107. In the sympathetic system the nerve impulses pass through ganglia on their way to and from the cord and brain.

The Sympathetic a Part of the Central Nervous System. The entire nervous system works together in governing the body, and it gives a wrong impression to speak of two systems. The sympathetic is, after all, only a branch of the central nervous system that is ruled without our knowledge by the cord and by the lower centers of the brain. It contains such a network of fibers that almost all the internal parts of the body are connected the one with the other, so that it is impossible for one of these organs to become deranged without affecting the other organs. The organs thus "sympathize" with each other, and for this reason the nerves to these parts are called the sympathetic system.

THE NERVOUS SYSTEMS OF OTHER ANIMALS

The great difference in the nervous systems of the higher and lower vertebrates is in the cerebrum. In the lower forms, as in the fishes, frogs, and reptiles, the cerebrum is small and smooth, and contains on its surface only a few of the nerve cells (gray matter) that in man are associated with the mind. In the higher animals, the cerebrum is greatly increased in size, and its surface becomes convoluted, making room for a great number of nerve cells on its surface. As a general statement, it is true that intelligence increases with the development of the cerebrum. The lower forms with small cerebrums are stupid, and higher animals with larger and more convoluted cerebrums are more intelligent. The cerebrum of man is the most highly developed of all, and man is the most intelligent of all animals.

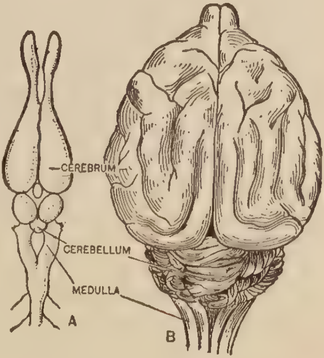


FIG. 108. The brain of a snake (*A*), and of a cat (*B*).

HYGIENE OF THE NERVOUS SYSTEM

The nervous system is so closely connected with all parts of the body that it is of the utmost importance to keep it in health. Good food and fresh air are necessary to the nerve cells, as they are to all other cells. In the special hygiene of the nervous system, the following points should be noted:

Sleep. Sleep is absolutely necessary to the nervous system. During sleep the nerve cells rest and prepare them-

selves for further work, and the idea that it is possible to sleep too much is probably incorrect. Babies should sleep from fifteen to twenty hours out of the twenty-four, older children from ten to fourteen hours, and adults from seven to ten hours. Occasionally a person is found who keeps in good health on five or six hours of sleep, and other persons are found who must have eleven or twelve hours. Most people under twenty years of age are better off with ten hours of sleep than with eight or nine hours, and most older persons keep in better health when they sleep nine full hours than when they sleep seven or eight hours.

There is no surer way to undermine the health than to stay up late at night and get up early in the morning, thus cutting short the hours of sleep. One who is doing this may think he is in good health, but if he will enter an athletic contest or do something else that will really put his nervous system to the test, he will find that he is not in the best condition. A runner who has been losing sleep has not the slightest chance of winning from others who have had long and regular hours of sleep. His nervous system cannot control his muscles quickly and accurately enough to prevent his falling behind in the race.

Tobacco. The evil effects of tobacco on the nervous system are generally recognized. Its weakening effect on the muscles has already been noted (page 74), and it seems to produce this effect more by interfering with the nervous regulation of the muscles than by injuring the muscle cells themselves.

Persons who use tobacco are often troubled with a restlessness and a jerkiness of movement, so that they cannot remain long in any one position. They are also subject to more or less constant trembling of the extremities, especially of the hands. Men who use tobacco seldom have the steadiness of

nerve required to make expert marksmen, and athletes who are training for contests of strength, endurance, or skill are not allowed to use tobacco in any form.

The effects of tobacco on the mind are more pronounced than its effects on the nervous control of the muscles. One class at Yale University was divided into four grades according to scholarship. Only 25 per cent of those in the highest division used tobacco, while 85 per cent of those in the lowest division were tobacco users. In another class 90 per cent of the first honor men were non-users of tobacco.

In young pupils the effects of tobacco on the mind are much more marked than are its effects in older persons. In a Chicago school, out of 125 boys who smoked, only two were able to keep up with their class. Nine tenths of these 125 boys belonged to educated, intelligent families; they had been given excellent school advantages; yet among them were found nearly all the boys who were from two to four years older than the average age of the children in their grade. In all, there were reported in Chicago 2402 pupils who were cigarette smokers, and only 6 per cent of them were able to do the school work of their grade. It is reasonable to believe that the use of tobacco had dulled the minds of these boys and had changed many of them from bright, active pupils into idling incompetents.

Tobacco also often leads to moral degeneration. Nothing is more fatal to ambition than tobacco, and to an extent it destroys the will power. A boy begins smoking a few cigarettes, and soon the habit has fastened itself on him so firmly and his will has been so weakened that he cannot break the habit, even when he realizes that he is injuring himself. The great majority of boys who smoke cigarettes are irritable, perverse, and careless of the rights of others. Our prisons and

reformatories are filled with those who began smoking cigarettes in youth. What would have been the fate of each of these persons if he had not used tobacco, is of course impossible to say; but there is no doubt but that many of them would have led successful lives if it had not been for cigarettes.

So well known are the effects of tobacco on the young, that in nearly all our states and in many foreign countries, stringent laws have been passed making it a crime to sell or give tobacco to boys under a certain age. One state has even prohibited the use of cigarettes in any form by old or young.

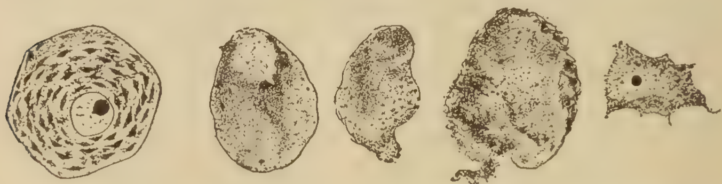


FIG. 109. At the left is a healthy nerve cell from a sympathetic ganglion. The others are nerve cells from one of the sympathetic ganglia of a man who died of alcoholic paralysis. Note the breaking down of the cells that the alcohol has caused.

Employers often favor those who do not use tobacco, and many employers will have nothing to do with tobacco-using boys. The evil effects of tobacco are known to the world, and this evil effect falls most heavily on the nervous system.

Alcohol. To tell the exact effect of a very small amount of alcohol on the nervous system is no more possible than to tell the exact effect of a small amount of alcohol on any other part of the body. When any considerable amounts of alcohol are taken, however, the entire nervous system is deranged. The following effects are very noticeable when alcohol is used to excess:

If enough alcohol is given to an animal to produce intoxi-

cation, in from ten to forty minutes the branches of some of the nerve cells will be found to be shrunken and gathered into little knots, and certain granules that are found in the protoplasm of nerve cells will have broken down. In long-continued excessive use of alcohol, many of the cells die, and it is also common for nerve fibers to degenerate and die, causing paralysis. Continued use of alcohol also causes a thickening of the connective-tissue membranes of the brain, and of the supporting tissue within the gray matter of the brain, so that the brain of a confirmed alcoholic contains fewer nerve cells and more supporting tissue than does a normal brain. In delirium tremens, some changes that are not at all understood occur in the nerve cells generally. With such changes in structure of the nervous tissue, we should naturally expect the great disturbances of function which alcohol causes.

Almost every one is familiar with the way the nervous system loses control of the muscles when it is under the influence of alcohol. The weakening of the muscles that follows the use of alcohol (page 74) seems to be due more to its effect on the nervous system than to the effect on the muscles themselves. The nervous system is as greatly influenced by alcohol in its other work, as in its work of regulating the muscles; the mind of an intoxicated person works no more accurately than his muscles work. Drunkenness may very properly be considered as temporary insanity, caused by the poisoning of the nerve cells by alcohol. Delirium tremens is a condition in which the cells have been so repeatedly poisoned that ideas are associated in the most grotesque and frequently terrifying manner.

The effects of alcohol on animals are very marked. Kittens that were daily intoxicated with alcohol lost all interest in

FIG. 110. These are normal kittens, and they are playing as healthy kittens do.

play, cleanliness, and mice, and showed no fear of dogs. They ate and slept, but took no interest in anything else, acting strikingly like animals from which the cerebrum had been removed. Dogs that had been given alcohol daily in moderate amounts showed the most extreme fear, howling

FIG. 111. These kittens have been given alcohol. They are stupid and sleepy, and have lost all interest in play. (From a photograph by Dr. C. F. Hodge.)

and cringing when a bell was rung or when the floor was struck, and awakening from their sleep to cower in terror or run and howl in an agony of causeless fear. This timidity continued after the giving of alcohol had been stopped, showing that the mental workings of the brain had been permanently injured.

The results of these experiments show the very great effect of alcohol on the mind. It is estimated that 20 per cent of insanity comes from this cause, and it is proper to conclude that just as alcohol injures the liver and kidneys, so it injures the nerve tissue; and as it interferes with the workings of the liver and kidneys, so it interferes with the function of the nervous system, both in governing the body and in its work as an organ of the mind.

Summary. The twelve pairs of cranial nerves rise from the brain. They supply the head and many of the internal organs. The thirty-one pairs of spinal nerves rise in the spinal cord. Each nerve has a set of ventral roots that contain the efferent fibers and a set of dorsal roots that contain the afferent fibers.

The sympathetic nervous system consists of a network of ganglia and fibers. It controls by reflexes the internal organs, the blood vessels, and the sweat glands. It is connected with the central nervous system and cannot carry on its work alone. It is called the sympathetic system because by it all the internal organs are connected and through it they "sympathize" with each other.

Intelligence increases with the development of the cerebrum. The lower vertebrates have small, smooth cerebrums and the higher vertebrates have larger and more convoluted cerebrums. The human cerebrum is the most highly developed of all.

Because the nervous system is directly connected with all parts of the body, it is very important to keep it in health. The special need of the nervous system is sleep, without enough of which we cannot have good health.

Tobacco interferes with the nervous control of the muscles. It also dulls the mind. It is especially harmful to the young, as is shown by the fact that only 6 per cent of 2402 cigarette smokers in the Chicago public schools were able to do their school work. Another effect of tobacco is a weakening of the moral nature.

Alcohol affects the structure of nerve tissue, the excessive use of alcohol causing many of the nerve cells and fibers to die. It also affects the function of nerve tissue, intoxication causing the nervous system to lose its control of the muscles and its mental power. The minds of animals are permanently injured by alcohol, and among human beings about 20 per cent of insanity is caused by it.

QUESTIONS

How many pairs of cranial nerves are there? Where do they rise? What part of the body do they supply?

How many pairs of spinal nerves are there? Where do they rise? What kind of fibers are in the dorsal roots? the ventral roots?

Of what does the sympathetic nervous system consist? How is the central nervous system connected with it? What part of the body does it control? Explain how a sympathetic reflex is carried out. Are we conscious of these reflexes? Can we control them? Why is this part of the nervous system called the sympathetic system?

What is the great difference in the nervous systems of the higher and lower vertebrates? What increases with the development of the cerebrum?

How much sleep is needed by persons of different ages? What is said of the importance of sleep?

What effect has tobacco on the muscles? How does it produce this effect? What did investigations at Yale University show in regard to the effects of tobacco on the students? How many of the 125 cigarette smokers in one Chicago public school kept up their school work? What per cent of the cigarette smokers in all the schools investigated did so? What effect has tobacco on the ambition? on the will power? As a rule, are cigarette smokers worried about their own condition and anxious to do better? Why have laws been made against selling cigarettes? Why do employers favor boys who do not use tobacco?

What is the effect on the nerve cells of an animal of sufficient alcohol to cause intoxication? How quickly does it produce this effect? What effect has long-continued and excessive use of alcohol on nerve tissue? on the supporting tissue of the brain? What effect has alcohol on the nervous control of the muscles? on the mental workings of the nervous system?

What effect had daily intoxication on kittens? What effect had moderate amounts of alcohol on the minds of dogs?

A reflex movement (Fig. 101) is quicker than the movement would be if the impulse had to go to the brain. Explain why. What advantage is there in having the body governed by reflexes that require no attention from the mind?

When the "funny bone" is struck, a nerve in the arm is crushed against the bone. What part of the body is affected? Explain why. Persons who have had a limb amputated sometimes complain of pain in the limb. What causes this sensation? Where is the trouble in a paralytic stroke?

CHAPTER XVIII

THE EFFECTS OF ALCOHOL ON THE HUMAN BODY

THE question of the use of alcoholic drinks is one that continually agitates our nation, and indeed has been receiving, for many years, the serious attention of the whole civilized world. The opponents of alcohol insist that it is the chief cause of poverty and crime, and they urge against alcohol the *physiological* argument that it injures the body. Other persons maintain that alcohol, in moderate quantities, is beneficial to the body.

We have already learned something of the effects of alcohol on many of the different organs of the body. The human body, however, is more than a collection of organs. It is one whole, and any physiological question must be looked at from the standpoint of the body as a whole. In this chapter we shall take up the effects of alcohol on the body from a more general view point.

What is Alcohol? Alcohol is a substance formed from sugar by a small plant called *yeast*. When yeast grows in water in which sugar is dissolved, it digests or *ferments* the sugar, breaking it up into water, carbon dioxid, and alcohol. The alcohol, like the carbon dioxid, is poisonous to the yeast if present in large quantities.

FIG. 112. Yeast plants.

Alcoholic Drinks. The most common alcoholic drinks are wine, cider, beer, and distilled liquors. Wine and cider are

made by allowing yeast to ferment the sugar in fruit juice. If it is apple juice that is fermented, the product is cider. If grape juice is fermented, the product is wine. Beer is made by allowing the yeast to ferment sugar from grain. The starch in the grain is first changed to sugar by sprouting the grain, after which it is ready to be fermented by the yeast.[1]

Brandy is manufactured by distilling fermented fruit juice. Whisky is made by distilling the fermented material from grain or potatoes, and rum by distilling fermented molasses. Beer contains on an average about 5 per cent of alcohol, wine contains about 10 per cent of alcohol, and distilled liquors contain about 50 per cent of alcohol.

Alcohol and Length of Life. If alcohol as it is commonly used is beneficial to the body, drinkers should live longer than those who abstain from alcohol. If alcohol injures the body, we should expect abstainers to be longer lived than drinkers. The best possible way, therefore, of settling the question as to whether alcohol injures or benefits the body is to compare the death rates of drinkers and of abstainers.

The United Kingdom Temperance and General Provident Institution is a life insurance company of London, England. For more than fifty years this company has kept separate lists of the moderate[2] drinkers and abstainers among its policy

[1] In distilling liquors, the liquid (the fruit juice or the water in which the grain has been soaked) that contains the fermented sugar is heated, and the vapor that comes from it is caught and condensed. The alcohol in the liquid is changed to vapor more easily than the water, and the liquors that are manufactured in this way are strong in alcohol.

[2] All insurance companies refuse to accept heavy drinkers, and they reject many persons who are very moderate drinkers indeed. The above statistics, therefore, apply only to those who were moderate drinkers at the time they were insured. Some of them may later have become excessive drinkers, but if all drinkers were included in the statistics, the death rate among the alcohol users would be very much higher than is here shown.

holders. Its records show that for every 74.3 deaths among abstainers, there are 100.4 deaths among the drinkers. The death rate is, therefore, 35 per cent higher among the users than among the non-users of alcohol. Many other life insurance companies have kept similar records, and in every case the death rate is from 25 to 50 per cent higher among the drinkers than among the abstainers. These averages have been made up from records including many thousands of lives, and there is no doubt of their correctness. They have been examined with great care to see if there was any reason other than the use of alcohol why the drinking man should die earlier than the non-drinker. No such reason can be found, and it is certain that the users of alcohol fail to live as long as those who do not use alcohol, because the alcohol weakens and injures the body.

Alcohol and Tuberculosis. We have already seen (page 171) that alcohol lowers the power of the body to resist disease germs. The relation of alcohol to tuberculosis deserves special mention.

In France, the districts drinking 12.5 liters of wine per capita had annually 3.3 deaths from tuberculosis for each one thousand inhabitants. The districts drinking 35.4 liters of wine per capita had annually 10.8 deaths from tuberculosis for each one thousand inhabitants. In the sanatoria for consumptives at Loslau, Germany, in 1899, 30 per cent of the patients were avowed alcoholics, 37 per cent were moderate drinkers, 27 per cent were occasional drinkers, and only 6 per cent were total abstainers. According to estimates made in France, 10.3 per cent of the children of drunkards suffer from tuberculosis, while only 1.8 per cent of the children of total abstainers have tuberculosis.

Statistics like these show clearly that alcohol users are especially subject to tuberculosis. So thoroughly established and so important is this fact, that in Paris, in 1905, the International Tuberculosis Congress, whose members include the most learned bacteriologists and physicians in all the world, adopted the following resolution: "We strongly emphasize the necessity and importance of combining the fight against tuberculosis with the struggle against alcoholism."

The Relation of Alcohol to Insanity. The great increase in recent years of the number of the insane has excited alarm, and considerable time has been devoted to studying the causes of insanity. From a careful study of the causes bringing on insanity in the patients in all the asylums in England, Wales, and Ireland, it is estimated that alcohol causes about 20 per cent of all insanity. In England, personal intemperance (intemperance of the insane person himself) causes nearly 15 per cent of insanity, and intemperance of the parents causes enough more to bring the total to about 20 per cent. When one thinks of the very great effect that alcohol has on nerve tissue, and of the way it affects the working of the mind, it does not seem at all strange that continued drinking should bring on insanity.

Alcohol and Heredity. Whether or not the children of those using alcohol are affected by the drinking of their parents is a question that cannot be neglected. That children are very greatly affected by drunkenness in their parents, the following facts make certain:

Two pairs of dogs, as nearly alike as possible, were selected. One pair was given alcohol in their food, and the other pair had the same food and care, without alcohol. Of twenty-three puppies of the pair of dogs that had alcohol, nine were deformed, ten were born dead, and only four lived. The

other pair of dogs in the same time raised forty-five puppies, four of which were deformed and forty-one of which lived. Thus, only 17.4 per cent of the puppies born to the alcoholic dogs lived, while 90.2 per cent of the much larger number born to the other dogs lived.

Much the same effect is produced in human families by alcohol. In ten alcoholic families investigated, there were fifty-seven children. Of these children, ten were deformed, six were idiots, six were epileptics, twenty-five failed to live, and only ten of the fifty-seven, or 17 per cent, were normal and healthy. In ten families not using alcohol that were investigated, there were sixty-one children. Of these, two were deformed, five failed to live, and fifty-four, or 88.5 per cent, were normal and healthy. One investigator estimates that only about 17.5 per cent of the children of drunkards are physically sound; another places the percentage at 11.7 per cent; and still another reports that of the children of drunken parents examined by him, not more than 6.2 per cent were strong and well. These facts show that the bodies of children are affected by the intemperance of their parents.

The minds of children are also affected by the drinking of parents, as the following facts show:

Of 8624 children of drunken parents, 53 per cent were mentally defective, while of 13,323 children of sober parents, only 10.1 per cent were unable to keep up with their school work. Of children whose ancestors had been free from alcoholic taint for three generations, 96 per cent were proficient in school work, while of those who had three generations of alcoholic ancestors, only 23 per cent were able to keep up with their classes, and 76 per cent had some nervous trouble.

We thus see that the evil effects of alcohol on both mind

and body are inherited. Professor Welch of Johns Hopkins University says, "The brunt of the evil heritage of alcohol falls on the nervous system of the second generation."

Alcohol and Character. The relation of the body to the mind is not understood. We do not know, therefore, how drugs affect the mind and character of a person, but we do know that drugs can do this. The continued use of opium will change an upright and honorable person into a shameless falsifier. Cocaine sometimes turns mere boys into desperate criminals, who do not shrink from robbery and murder. Alcohol also has a great effect on the character. By intoxication, some mild and kind men are changed into cruel and dangerous persons, and the breaking down of the will power and character in confirmed drunkards is something with which many people are familiar.

The following facts show that, in the opinion of business men, drinking renders men on the whole less faithful, honest, and efficient. Bonding companies are suspicious of drinking men, and often refuse to furnish bonds for men who frequent saloons. The Fifth Avenue National Bank of New York City has for thirty years forbidden even its clerks and messenger boys to drink in saloons and barrooms. Many large railroads refuse to employ drinking men in their operating departments, and some of them refuse to employ drinkers even as bookkeepers or ticket agents. Shrewd business men everywhere, in employing men, give the preference to abstainers over drinkers. Any young man seeking employment in a responsible position will soon learn that one of the first questions asked an applicant is whether or not he drinks.

Conclusion. We find that alcohol shortens life; that it makes the users of it more susceptible to germ diseases, the

relation of alcohol drinking to tuberculosis showing this in a striking way; that alcohol causes a considerable amount of insanity, and that the drinking of parents has a very injurious effect on the bodies and minds of their children. We also find that alcohol has a tendency to destroy the will power and the character of those who use it.

These are facts that must be faced by any one investigating the effects of alcohol on the human body. The only answer that can be made to these facts is that it is the *abuse* and not the *use* of alcohol that works all this evil. This is a question that need not be discussed here, for practically every one who uses alcohol at all uses too much of it (page 131). When it is used as mankind uses it, its effects are the evil effects given above.

QUESTIONS

How is alcohol formed? What is cider? wine? beer? How are distilled liquors manufactured? How much alcohol is in wine? in beer? in distilled liquors?

What figures are given as to the death rates of drinkers and abstainers? Why must these figures be regarded as reliable?

What reasons are there for thinking that in France wine drinkers are especially subject to tuberculosis? What facts from Europe indicate that alcohol increases consumption? What effect has alcohol drinking on the amount of tuberculosis among the children of the drinkers? What is the opinion of the International Tuberculosis Congress in regard to the connection between alcoholism and tuberculosis?

What per cent of insanity, according to estimates made in England, is due to alcohol? Tell something of the effects of alcohol on the children of the drinkers. What effect does alcohol often have on the character? What facts show that business men consider alcohol users less trustworthy than non-drinkers?

CHAPTER XIX

THE SPECIAL SENSES: Touch, Taste, Smell, and Hearing

PART of the nerve impulses that are carried into the brain cause reflex actions; part of them cause *sensations*. It is difficult to describe a sensation, but we have all experienced sensations of light, sound, touch, heat, cold, and hunger. There is, therefore, no difficulty in understanding the meaning of the term.

General Sensations. Hunger is caused by afferent impulses from the stomach, and thirst by impulses from the pharynx. Afferent impulses from the muscles (for every muscle has great numbers of afferent as well as efferent nerve fibers ending in it) cause the sensation of tiredness, and other impulses give rise to feelings of pain, nausea, and other sensations. These impulses rise *within the body;* they originate because of some condition of the body, and they cause what are called the *general sensations.* Most (but not all) of the general sensations are caused by impulses that come from all parts of the body.

Special Sense Organs. In some parts of the body are *special sense organs.* In these the afferent nerve fibers end in such a way that they are stimulated *from without the body.* The sense organs are the eye, the ear, the nose, the epithelium of the tongue and mouth, and the skin. The nerves in the eye are stimulated by light; the nerves in the ear by sound waves in the air; the nerves of smell by odors; the nerves of

taste by substances dissolved in the mouth; and the nerves in the skin by touching objects, and by heat and cold. The impulses that are thus started in these nerves travel up to the brain and cause sensations of light, sound, smell, taste, and touch. *Seeing*, *hearing*, *smelling*, *tasting*, and *feeling* are the five special senses, and by these senses we learn all that we know of the world about us.

TOUCH

Afferent Nerve Endings in the Skin. The upper surface of the dermis is thrown into papillæ that stand up like little

FIG. 113. Afferent nerve endings. *A* shows a nerve fiber in the skin ending at the bases of tactile cells. *B* shows a nerve fiber with free endings among the cells of the skin. The nerves of glands and of involuntary muscles, and the afferent nerves of voluntary muscles, end in this way. *C* shows a nerve fiber ending in a bulb of connective tissue. Many nerve endings of this kind are found in the lower layers of the skin, and in the internal parts of the body.

mountain peaks under the epidermis. Some papillæ of the skin (Fig. 93) contain only blood vessels, but in other papillæ

tactile corpuscles (Fig. 94) are found. These are small, oval bodies, in which one or several nerves of touch end. The tactile corpuscles are especially abundant in the fingers and toes.

Other nerves of touch branch at the ends, and have on the tip of the branch a little saucer-like expansion that fits around the base of an epidermal cell. Such a cell is called a *tactile cell.* Still others of the afferent nerve fibers of the skin end in many small free branches among the epidermal cells.

How we feel. When we touch anything, the epidermis is pressed down on the ends of the nerves of touch. This starts an impulse up the nerve to the brain, and causes a sensation of feeling. If all the nerve endings in the skin that is being touched have the same amount of pressure on them, we know that we are feeling a smooth surface. If some of them are being pressed harder than others, we know that the surface is rough. We know what part of the body it is that is touching an object because we know which nerves are bringing the impulses. We know whether the object is large or small by the amount of skin that is touching it, and by the distance that we must move the hands to pass them over it. The mind is thus able to judge of many things by the nerve impulses that come to it through the nerves of touch. That it may form mistaken judgments from these impulses, you can prove by crossing your fingers (Fig. 114) and rubbing the point of your nose so that it will touch the outer edge of one finger and the inner edge of another finger. It will seem as though you had two noses, because ordinarily

FIG. 114.

it takes two objects to touch the fingers on their edges as the nose is touching them, and the mind has come to think that there are two objects when impulses come from these points at the same time.

Different Kinds of Afferent Nerves in the Skin. In the skin are nerves that are stimulated by touch, others that are stimulated by heat, and others that are stimulated by cold. Whether there are special nerves of pain, or whether any afferent nerve fiber, if stimulated in the wrong way, will cause pain, is not known. When the epidermis is removed, as by a burn, all sensations of touch, heat, and cold are lost, and only sensations of pain come from the part. That the nerves in the skin do not all do the same kind of work you can easily prove by the following experiment:

Fill a small test tube with warm water, or warm the end of a wire or other piece of metal, and pass it slowly over the skin of the forearm. In certain spots you will feel a sensation of warmth. Mark these places by small drops of ink, and then pass a cold object over the same area of skin. Note that the nerves for feeling cold are not in the same place as the heat nerves. Also note that nerves of touch are found where there are neither heat nor cold nerves.

Where the Sense of Feeling is Best. In some parts of the skin the nerve endings are very abundant, and in these places the sense of touch is acute. In the tip of the tongue it is most acute of all. It is also very highly developed in the lips, in the tip of the nose, and in the finger tips. Thrust two pins through a thin piece of cork (Fig. 115) and touch them to the finger tip. Here you can feel the two points when they are only one twelfth of an inch apart. But if you touch them to the back of the hand or forearm, they will feel like one point unless you

FIG. 115.

place them much farther apart. On the tip of the tongue we can distinguish two objects that are only one twenty-fifth of an inch apart, while on the back of the body two objects must be separated by two and one half inches before we can tell whether one or two points are touching us. The following is an interesting experiment:

Thrust two pins through a piece of cork, and while some member of the class is blindfolded, or looking the other way, touch his skin on the finger tips, back of the hand, forearm, lips, cheek, neck, etc. Sometimes use one pin and sometimes two, and measure how far apart the two must be separated before they can be distinguished on the different parts of the body.

TASTE

The nerves of touch are all over the body, but the nerves of taste end only in the tongue and in the epithelium[1] of the back part of the mouth. The taste nerves branch out and end free among the epithelial cells, and in some places in the tongue they end in a special way in little bodies that are called *taste buds*. A taste bud is composed of an outer circle of long cells, set edge to edge, as the staves are arranged in a barrel. It is buried in the epithelium of the tongue, and at the tip of the bud is a small opening out into the mouth. Within the bud are long, slender *taste cells*, the tips of which stand up out of the opening in the end of the bud. Within the taste bud the nerves of taste are connected with the taste cells.

FIG. 116. A taste bud.

Before anything can be tasted, it must first be dissolved. Then the little molecules of the substance work down in

[1] The outer layer of cells in a mucous membrane is called the *epithelium*. It corresponds to the epidermis of the skin.

among the taste cells and so affect them that they start impulses in the nerve fibers behind them. These impulses go to the brain and cause sensations of taste.

SMELL

The *olfactory nerves*, or nerves of smell, end in the lining of the upper front part of the nasal cavities. In the mucous membrane of these parts are long, slender cells called *olfactory cells.* They lie between the epithelial cells, and their outer ends are divided into fine cilia-like processes. From the inner end of the olfactory cells nerve fibers pass to the brain. The olfactory cells are in reality nerve cells that have grown down from the brain above, and they are the only nerve cells in the body that are exposed to the outside world.

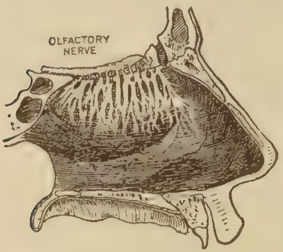


FIG. 117. The olfactory nerves.

How we smell. From anything that has an odor, molecules are flying off into the air. These molecules pass into the nasal chamber, come into contact with the olfactory cells, and there cause changes that start impulses up the olfactory nerves. Drawing the air up into the nose brings the molecules up to the olfactory cells, and we therefore sniff the air when we wish to smell anything.

FIG. 118. A portion of the olfactory mucous membrane. The slender cells with the cilia-like processes on them are the olfactory cells.

In certain animals the sense of smell is much more highly developed than it is in man. Some kinds of dogs can follow

the track of an animal or man many hours after the trail has been made, and bees and some other insects are also far more keen-scented than is man.

Care of the Olfactory Organ. Inflammation destroys the delicate olfactory cells, and when they have been destroyed they are not renewed. Inhaling dust is a common cause of inflammation of the mucous membrane of the nose, and taking cigarette smoke into the nose is very injurious to the olfactory cells. Catarrh should have medical treatment, for by it the sense of smell is partially destroyed in many persons, and it may lead to more serious diseases.

HEARING

Hearing is caused by waves of air striking against the ear. In order to understand this subject, it is necessary to understand something of the nature of air. In solid bodies, the molecules cannot move about from one place to another. In liquids, the molecules move about and slip over each other, but they do not separate. In gases, the molecules are not held together, but separate and fly off from each other.

The air is a mixture of gases (page 178), and if the air molecules were visible, you would see the molecules of the different gases dancing and flying about and striking against each other. When the wind blows, the molecules are flying along. When the wind pushes against you, the many little molecules of which the air is composed are flying against you and striking you. In a great gale the air may be traveling at the rate of a mile a minute, and in very great storms it may even have a speed of two miles a minute. With a speed like this, its molecules strike objects in their path with tremendous force, uprooting trees, carrying away houses, and overturning large and heavy objects.

Sound Waves. When you throw a stone into water, the stone strikes against the molecules of water and sets them in motion. The molecules which are set in motion by the stone strike against those next to them; these in turn hit the next set, and a wave runs out in the water. When a bell is rung, the bell vibrates and strikes the air molecules next to it, setting them in motion. These strike the next molecules, and so on, and a wave runs out through the air. When these air waves strike the ear, they start impulses in the auditory nerve, the impulses are carried to the brain, and we hear the bell ring. Big air waves cause loud sounds, and small waves cause slight sounds. Great sound waves may strike the ear with such force as to break the *tympanic membrane* (Fig. 119), and they may also break windows and jar houses.

The Ear. The ear is an organ so constructed that when the sound waves strike it, the afferent nerves in it will be stimulated. It is divided into three parts, — the *external*, *middle*, and *internal ear*.

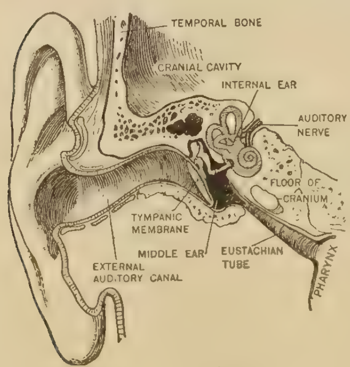


FIG. 119. The ear.

The External Ear. The external ear includes the part that we see and the canal (*auditory canal*) leading in to the middle ear. The external ear is composed of a piece of cartilage covered with skin. Its function is to catch the sound waves and turn them down the canal to the middle ear. When animals are listening intently, they hold up their ears to catch as much of the sound waves as possible, and a man sometimes holds his hand behind his

ear to help in turning the sound waves down the canal to the middle ear.

The Middle Ear. The middle ear is a little cavity in the temporal bone of the skull. The cavity is shaped like a drum, and is often called the *tympanum*, or ear drum. At the inner end of the auditory canal is the tympanic membrane. This stretches like a piece of thin skin across the bottom of the canal, and separates the external ear from the tympanum. The cavity of the tympanum is filled with air.

The Bones of the Ear. In the middle ear are three very small bones, — the *malleus* (hammer), the *incus* (anvil), and the *stapes* (stirrup). The malleus is fastened to the tympanic membrane, the stapes fits into an opening that leads into the internal ear, and the incus is between the malleus and the stapes. These three bones stretch across the middle ear from the tympanic membrane to the inner wall.

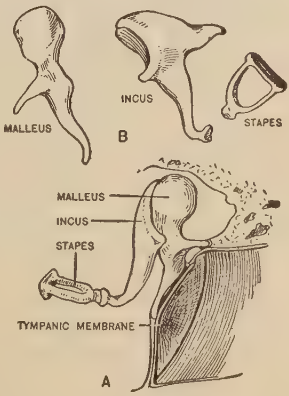


FIG. 120. Bones of the ear.

The Eustachian Tube. The *Eustachian tube* is a narrow passageway that leads from the middle ear to the pharynx. It enters the pharynx high up in the side wall, opening almost into the back part of the nasal chamber. Through the Eustachian tube the air passes out of and into the middle ear, and keeps the pressure of the air within the tympanum the same as the outside air pressure. If a Eustachian tube becomes closed,[1] the varying pressure

[1] In colds, catarrh, scarlet fever, measles, pneumonia, and in some other diseases, inflammation may extend up the Eustachian tubes and cause deafness

of the atmosphere caused by changing conditions of the weather and by passing to the lighter atmospheres of higher altitudes or the heavier atmospheres of lower altitudes, causes an unequal pressure on the two sides of the tympanic membrane. This causes deafness.

The Internal Ear. The internal ear lies deep in the temporal bone, and is divided into three parts. The central part is the *vestibule;* the front part, which is coiled like a snail shell, is the *cochlea;* and the back part is the *semicircular canals.* The entire internal ear is filled with fluid. Standing out in this fluid from the walls are slender, hair-like cells, that at their inner ends are connected with the fibers of the *auditory nerve.* The impulses that cause us to hear come from the cochlea.

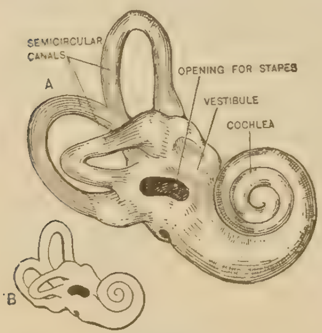


FIG. 121. The internal ear. *B* shows the natural size of the internal ear.

How a Sound is heard. The external ear catches the sound wave and turns it down the auditory canal, at the bottom of which the wave strikes the tympanic membrane. The membrane swings out and in, and sets the chain of bones in motion. The malleus pushes on the incus, and the incus on the stapes. The stapes is thus forced in against the fluid in the vestibule and in this fluid waves are set up which run through the internal ear, striking against and moving the hair-like cells that project into the fluid. This starts im-

by closing the tubes (page 270). Adenoid growths often close the Eustachian tubes and start inflammation in them. Probably two thirds of all deafness and ear trouble comes from this cause.

pulses that travel up the auditory nerve to the brain, and causes a sensation of sound.

Function of the Semicircular Canals. The semicircular canals are not concerned in hearing, but *their function is to assist in retaining the equilibrium of the body.* One canal lies behind the vestibule in a vertical plane, and if the head moves forward or backward in the way that it moves in nodding, the fluid in this canal is set in motion. Another canal runs outward from the vestibule in a horizontal plane; when the head is turned to the side, as when one turns the head to look over the shoulder, the fluid in this canal is set in motion. The other canal runs up and outward from the vestibule in a vertical plane, so that if the head moves toward the side in the way it does when it is bent over toward the shoulder, the fluid in this canal moves.

If the body leans in any direction, the fluid in one or more of these canals is always set in motion, and impulses are sent to the brain, bringing information in regard to the direction in which the body is beginning to fall. Impulses are then sent out from the brain that cause the proper muscles to contract and bring the body again to the upright position. Sometimes the semicircular canals become diseased, and then there is great difficulty in retaining the equilibrium of the body, because it is not noticed that the body is beginning to fall. Sight and impulses from the muscles assist in keeping the equilibrium, but a prominent part of this work is done by the semicircular canals.

Care of the Ears. A blow on the side of the head is dangerous, for it may send such a strong air wave down the auditory canal that the tympanic membrane will be ruptured. Live insects in the ear may cause great distress by buzzing and moving about. They can be drowned by pouring oil or water

into the ear. No one but a physician should attempt to remove these or other objects from the ear,[1] because in doing so there is great danger that an unskilled person will injure the lining of the auditory canal or break the tympanic membrane.

The hearing may be injured by quinine, and this should be taken for any considerable time only under the advice of a physician. Earaches and deafness are caused by various troubles, very often by catarrh that has spread up the Eustachian tube and affected the middle ear. Earache may sometimes be prevented at night by wearing a hood or nightcap while sleeping, but wearing cotton in the ears and pouring oil and other liquids into them often brings on serious trouble, and should not be practiced. Children with ear trouble should have the prompt attention of a skilled physician or they will often suffer great pain needlessly, and perhaps will have the hearing permanently impaired. Among adults about one third have the hearing affected in one or both ears largely because of neglect in youth.

Summary. Some of the afferent nerve impulses cause sensation. General sensations are produced by impulses that arise within the body. In the special sense organs the nerves end in such a way that they are stimulated from outside the body. Seeing, hearing, smelling, tasting, and feeling are the special senses.

The afferent nerves of the skin end in tactile corpuscles, at the bases of tactile cells, and in free nerve endings. In feeling objects, stimuli are started in the nerves by pressure; and from these stimuli the brain forms many judgments in

[1] The bitter wax in the auditory canal is secreted by small glands in the skin. It is a protection against insects. Scraping the wax out of the ears with the head of a pin or other piece of metal may cause the lining of the auditory canal to become inflamed, and greatly increase the quantity of wax secreted.

regard to the things that we touch. In the skin are nerves of touch, heat, and cold, and possibly nerves of pain. The sense of touch is acute in the tip of the tongue, lips, and finger tips, and much less acute in some other parts of the body.

Many of the fibers of the nerves of taste end free in the mucous membrane of the tongue and of the back part of the mouth. Other fibers end in taste buds. Before anything can be tasted it must be dissolved.

The olfactory cells are nerve cells in the nasal mucous membrane. Impulses are started in these cells by odors. The olfactory cells are delicate nerve cells, and if they are destroyed, the sense of smell is permanently lost.

A sound wave is produced by setting in motion the molecules of the air. When these waves strike the ear, they cause us to hear.

The ear is composed of the external, internal, and middle ear. The external and middle ears are separated by the tympanic membrane. The middle ear contains the malleus, incus, and stapes. The Eustachian tube puts the air in the middle ear into communication with the outside air. The internal ear is composed of the vestibule, cochlea, and semicircular canals. The canals assist in preserving the equilibrium of the body.

When a sound wave strikes the external ear, it is turned down the auditory canal and sets in motion the tympanic membrane. This moves the chain of bones in the middle ear, and they set up waves in the fluid in the internal ear. These waves start impulses in the nerves of hearing that are carried to the brain, and cause sensations of sound. The ear should have intelligent care, for many cases of defective hearing come from neglecting ear troubles in children.

QUESTIONS

What causes sensations? Name some of the general sensations. Where do the nerve impulses that cause these sensations originate? Name the special sense organs. How are the nerve endings in each one stimulated?

Give three ways in which the afferent nerves end in the skin. How are impulses started in these nerves when we touch an object? Explain how we are able to judge of certain properties of objects by touching them. What different kinds of nerves end in the skin? Where is the sense of feeling acute? Where is it least acute?

Give two ways in which the nerves of taste end in the tongue. Describe a taste bud. How is the nerve of taste stimulated? Does a chicken taste corn when it eats it?

Where is the organ of smell located? Describe the olfactory cells. What kind of cells are they? What is an odor? How are impulses started in the olfactory cells? In what ways may these cells be injured?

Of what is air composed? Explain how a bell starts waves in the air. How do these waves cause the sensation of sound?

Name the three divisions of the ear. What is the function of the external ear? What is the middle ear called? Why? What and where is the tympanic membrane? Name the bones of the ear Where are the Eustachian tubes? What is their use?

Name the parts of the internal ear. With what is it filled? Explain how a stimulus is started in the auditory nerve. What is the function of the semicircular canals? How are the impulses started in the nerves that are connected with these canals? When one whirls himself rapidly about and then stops, what causes him to have a sensation of dizziness?

How may a blow on the ear injure the hearing? How may an insect in the ear be killed? What is a common cause of earache and deafness? Why should ear troubles in children receive attention?

CHAPTER XX

THE SPECIAL SENSES (Continued): SEEING

ALL space is filled with an invisible substance called *ether*, and light is waves in the ether. The eye is so constructed that when the ether waves enter it, they stimulate the afferent nerves and start impulses to the brain that cause the sensation of sight.

Protection of the Eyes. The eyes are very important and very delicate organs, and must therefore be well protected. The deep bony eyesockets are a great protection from blows. The inside of the eyesocket is lined with a layer of fat which forms a soft cushion for the eyes to rest and turn on, and if the eye is struck, the fatty layer between it and the bone assists in preventing injury.

The eyelids, eyelashes, and eyebrows also assist in protecting the eyes. The eyelids screen them from dust and light, and close if a blow is threatened. The eyelashes guard the eyes from dust and light, and the eyebrows keep the sweat from running down from the forehead into the eyes.

The Lachrymal Glands. In the outer corner of each upper eyelid is located a *lachrymal gland*, very similar in structure to a small salivary gland. These glands secrete the tears and pour them into the eyes at the upper outer corners. The tears flow down across the eye to the inner corner, where they enter the *lachrymal duct*, which carries them down into the nasal chamber. In their passage across the eyes, the tears cleanse

the eye, washing away dust and germs. The workings of the lachrymal glands give us another illustration of the effect of the mind on the body; for sorrow, pain, and sometimes anger cause them to secrete so abundantly that the tears cannot all be carried away by the lachrymal ducts, but overflow on the cheeks.

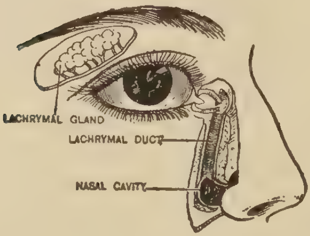


FIG. 122. The lachrymal gland and duct.

The Meibomian Glands. In the eyelids are small glands called the *Meibomian glands.* They are very similar to sebaceous glands, and empty out an oily secretion along the edges of the eyelids. Water does not flow freely over an oiled surface, and the secretion from the Meibomian glands prevents the tears from overflowing the eyelids. When the eyelids are inflamed and congested, the Meibomian glands sometimes become diseased, and the secretion from them dries around the roots of the eyelashes, forming scales very similar to dandruff.

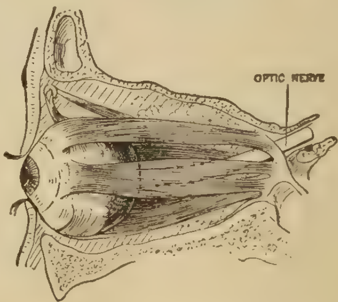


FIG. 123. The muscles of the eye.

The Muscles of the Eyes. There are six muscles to move each eye. The back ends of these muscles are attached to the walls of the eyesocket. The front ends are attached to the ball of the eye. By these muscles, the eyes can be turned in any direction, so that it is not always necessary to turn the head toward the object at which we are looking.

The Structure of the Eye. The eye has three coats. The outer one is the *sclerotic* coat, the middle one is the *choroid* coat, and in the back part of the eye is a third inner coat called the *retina*. The *optic nerve* enters the eye at the back and spreads out in the retina.

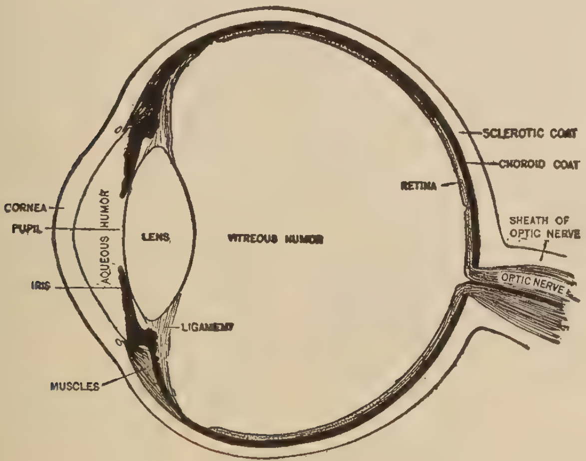


FIG. 124. A diagram of a section of the eye.

The interior of the eye is divided by the *lens* and the ligaments that support the lens into a small *anterior chamber* and a larger *posterior chamber.* The posterior chamber is filled with a transparent, jelly-like substance, called the *vitreous humor.* The small anterior chamber is filled with the *aqueous humor*, a watery fluid similar to tears.

The Sclerotic Coat. The sclerotic coat, or white of the eye, is composed of dense, closely woven connective tissue. It has a white color, except in front, where it is transparent. This transparent part is called the *cornea*, and through it the

light passes into the interior of the eye, as light passes through a window into a house.

The Choroid Coat and the Iris. The choroid coat is a loose connective tissue coat. It contains pigment that gives it a rich, dark color similar to the inside of a grape skin. The front part of the choroid is called the *iris*. This contains a circular opening, the *pupil*, in its center. The iris lies behind the transparent cornea, and being seen through the cornea, gives the color to the eye. A person is black-eyed, brown-eyed, or blue-eyed, according to the pigment in his iris.

The Function of the Iris. *The function of the iris is to regulate the amount of light that enters the eye.* In the iris are circular muscle fibers, running around the pupil, and when these contract, they make the pupil smaller. Other muscle fibers run in from the outer edge of the iris to the pupil, and when these contract, they enlarge the pupil.

FIG. 125. One cat has been in the dark; the other has been in the light.

The control of the size of the pupil is carried on by involuntary reflexes. When a strong light enters the eye, the circular fibers in the iris contract and diminish the size of the pupil. When the light is weak, the pupil is enlarged and more light is admitted to the eye. When you step out of a brightly lighted room into the dark, you cannot see, because the pupil is too small to allow enough light to enter. But if you remain out in the dark, the pupil will be enlarged and admit more light, and your vision will become better. When you step from a darkened room out into the bright sunshine, the light dazzles the eyes, because the opening in the pupil

is too wide and lets in too much light. After a few minutes, the muscles of the iris contract and diminish the size of the pupil, thus adapting the eye to the bright light.

The eye of a cat shows very distinctly the changes in the size of the pupil. In the dark the pupil is large and round, and in a bright light it is narrowed to a slit. This you can easily see for yourself by examining the eye of a cat that has been in the light, and then shutting the cat in a dark room or closet and examining its eye again, or you can see the expansion and contraction of the pupil in your own eye by the following experiment:

Stand facing a window and examine the pupil of your eye in a mirror. Now cover the eye for a few moments with your hand, remove the hand quickly, and watch the pupil. When a person is in health, the pupil should promptly expand when the eye is covered and contract when the eye is exposed to the light.

The Lens. The lens (Fig. 129) lies close against the back of the iris. It is thin at the edges and thicker in the middle, and is composed of a clear, jelly-like substance. The lens is inclosed in a circular sac, and both the sac and the material in it are transparent, so that the light can pass through them to the retina in the back of the eye. The lens is attached to the choroid coat by the *suspensory ligament*, which runs out all around from the outer edge of the lens. Figure 124 shows the lens and the suspensory ligament as they appear when cut across, but you must understand that the lens is circular like a coin, and that the suspensory ligament is a ring with the lens fitted into the opening of the ring.

The Function of the Lens. *The function of the lens is to form images of the objects that we see, and to accommodate the eye to near and distant objects.* In forming images in the

eye, the lens is assisted by the curved surface of the cornea. On the ground glass in the back of a camera, you can see an image formed by the lens in the front of the camera. The lens and cornea of the eye form images on the retina in the same way that the image on the camera is formed.

How a Lens forms an Image. Hold a convex lens[1] so that sunlight will pass through it. You will find that the lens brings the rays of light to a focus, — that is, it bends them so that they all meet in one point. It does this by changing the

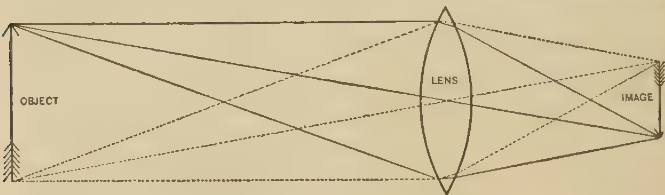


FIG. 126. Image formed by a convex lens.

directions in which the light waves are running, causing them all to run toward one point. The lens of the eye bends all the rays of light that *come from one point*, so that *they meet in one point on the retina of the eye.* In Figure 126 you can see how all the rays of light from the point of the arrow meet in one place and form an image of the arrow point. In the same way, an image of the other end of the arrow is formed, and *of every other point in the arrow*, and all these points together make an image of the arrow. So, in looking at a landscape, an image of the whole landscape is formed in the eye, all the rays of light that come from any one part of the scene in front of the eye meeting in one point and forming an image of that point on the retina. The

[1] This experiment can be performed with the lens in a pair of convex spectacles.

images that are formed in the eye, like the images in a camera, are upside down, and the right and left sides are reversed.

The Retina. The retina contains slender, pointed cells that are affected by light. These cells are connected with the optic nerve, and when light strikes the retina an impulse is started which passes back through the optic nerve to the brain.

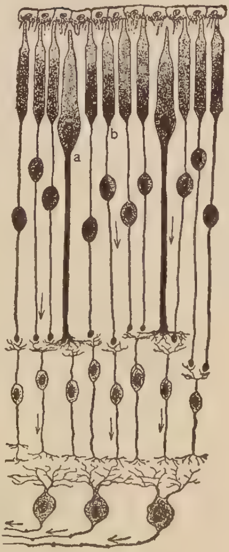


FIG. 127. When light strikes the retina, impulses are started in the long, slender cells (*a* and *b*) of the retina. These are carried to the brain, and cause the sensation of sight.

The Function of the Brain in seeing. Impulses are started in the eye by the images that fall on the retina, but these impulses must be carried to the brain before the sensation of sight is produced. From the impulses that come into the brain from the eye, we form judgments in regard to the form, size, color, and smoothness or roughness of objects. From these impulses we can judge also of the distance of objects from us, of their relative positions, and of their movements. That the mind does not always form correct judgments from the impulses that come from the eye, you can easily demonstrate by looking at the two lines of the same length in Figure 128.

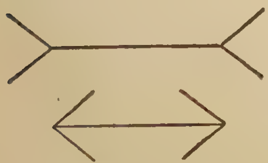


FIG. 128.

The Accommodation of the Eye. The shape of the lens must be changed according to the distance from the eye of the object that we are looking at. When the object is

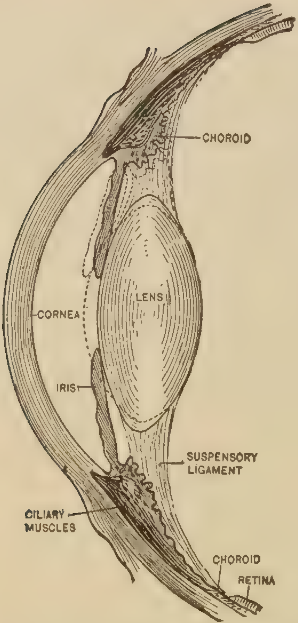


FIG. 129. When the ciliary muscles contract they draw forward the choroid coat, loosen the suspensory ligament, and allow the lens to become more convex.

close to the eye, the lens must be made more convex; for a distant object the lens needs to be flattened. This change in shape of the lens is called the *accommodation* of the eye and is brought about by the *ciliary muscles*.

How the Eye is accommodated. The suspensory ligament is attached to the choroid coat as is shown in Figure 129. The front ends of the ciliary muscles are attached to the sclerotic coat. Their other ends are attached to the choroid coat. When these muscles contract, *they stretch the choroid and draw it forward.* This *loosens* the suspensory ligament, and the lens of itself rounds out and becomes more convex. When the ciliary muscles relax, the stretched choroid returns to its former position, thus *tightening* the ligament again and flattening the lens.

The change in shape of the lens can be illustrated with a small sac, or with the swimming bladder of a fish, filled with air or water. Pull on the ends of the sac, and you will flatten it. Decrease the pull, and of itself the sac will round up, as does the lens when the ligament is loosened by the choroid's coming forward. You should take especial care to note that the contraction of the ciliary muscles *loosens* the ligament, and does not tighten it, for pupils who are

studying the eye often get an incorrect idea in regard to this point.

Near-sightedness. The image in the eye must fall exactly on the retina, or vision cannot be distinct. In some persons, the eyes are long from the front to the back. In such persons, the rays of light meet *before they reach the retina.* This makes an indistinct image, as does a camera, microscope, or field glass, when it is out of focus. In *B* (Fig. 130) you can see how the rays of light from the head of the arrow meet in front of the retina, and how, when they reach the retina, they have crossed and separated again, scattering the image on the retina instead of making it clear and distinct at one point. In such an eye, the images of the different points overlap, and a blurred, indistinct image of the whole object is the result. Near-sighted persons usually have prominent eyes, and the cornea usually is more convex than it is in the normal eye.

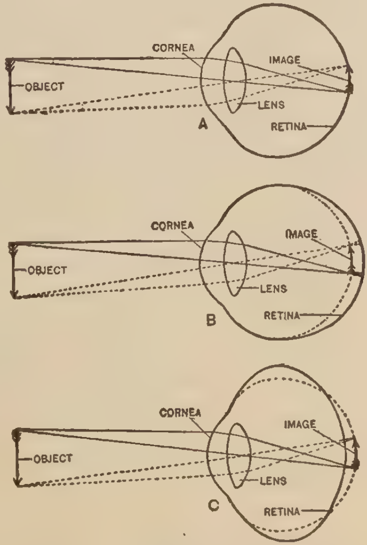


FIG. 130. *A*, normal; *B*, near-sighted; and *C*, far-sighted eye.

Far-sightedness. A far-sighted eye is too short from front to back. In such an eye, the retina is so close to the lens that the rays of light have not been brought together when they get to it, and the image is blurred (Fig. 130 *C*). Persons with eyes of this kind see distant objects best, because the rays from these objects meet more quickly than do those

from near objects. In a far-sighted eye, the cornea is usually flatter than it is in the normal eye, and in far-sighted persons the eyes are not so prominent as they are in near-sighted persons.

Astigmatism. In astigmatism, the curvature of the cornea is uneven, some parts being flatter than other parts. The rays of light that pass through the flatter places on the cornea are not brought to a focus as soon as the rays passing through the more convex parts. A distinct image cannot be formed in such an eye, for the lens cannot be so shaped that all the rays from one point will come together in a single point on the retina.

Eyes of Old Persons. In old persons, the material of which the lens is composed becomes harder and less fluid, and when the suspensory ligament is slackened, the lens fails to change its shape. The power of accommodation is thus lost. One of the most wonderful things about the eye is the way it accommodates itself to objects at different distances, and in old persons this power is to a certain extent lost.

Spectacles. If a sharp, clear image is not formed on the retina, eye trouble is certain to result. Near-sighted, far-sighted, and astigmatic eyes need spectacles or eyeglasses to assist in forming distinct images on the retina. The kind of lenses that are needed in the spectacles depends on where the image falls in the eye, each particular eye needing to be fitted with a lens that will cause the image to fall exactly on the retina.

Concave lenses spread the rays of light farther apart. If a concave lens is placed before a near-sighted eye, the lens will spread the rays of light and cause them to meet farther back in the eye (Fig. 131). A person who is very near-sighted will need a strongly concave lens, and a person who is only

a little near-sighted will need only a slightly concave lens. Each eye needs a lens that will bring the rays to a focus on the retina.

Convex lenses bend the rays of light together and cause them to meet more quickly. In far-sighted eyes, the rays have not yet met when they reach the retina, and by placing a convex lens before such an eye, the rays can be brought together and made to meet on the retina.

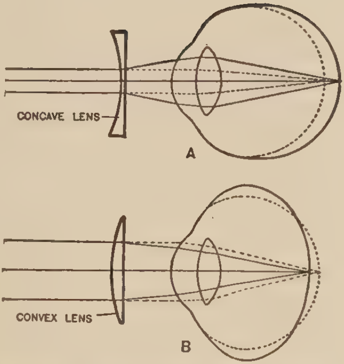


FIG. 131. How glasses cause the rays of light to meet on the retina.

In astigmatic eyes, the lens must be ground to suit the eye. Where there is a little hill on the cornea, a concave place must be ground out in the lens, and where there is a flat place on the cornea, the lens must be convex. Old persons need one pair of glasses for seeing distant objects, and another pair for seeing near objects.

HYGIENE OF THE EYES

It is a great mistake to think of the eye as a separate part of the body, doing its work without connection with the other body parts. Like all the other organs, it is intimately related to the rest of the body, and any defect or trouble in the eye is likely to affect other organs, the nervous system, and the general health. It is, therefore, important to care for the eyes, not only to relieve pain in the eyes themselves and to have good vision, but for the purpose of keeping the entire body in health.

Care of the Eyes. *Spectacles or eyeglasses should be worn when they are needed.* These should always be secured from a reliable physician or eye specialist, and not from some unskilled person or traveling optician, for it requires considerable skill and care to examine an eye, and to tell exactly the kind of lens that is suited to it. Also, the eye sometimes changes very rapidly, so that the lenses of the spectacles need to be changed, and it is always better to deal with some one who can examine the eyes from time to time, and change the lenses as changes are needed.

The importance of having the eyes properly fitted with glasses cannot be too strongly insisted on, for many cases of nervousness, headache, indigestion, nausea, and mental dullness vanish as if by magic when glasses are adjusted to the eyes.[1] If a person has any signs of eye trouble, or if he has headaches and stomach trouble for which there seems to be no reason, the eyes should be examined at once.

A good light should always be used in reading or in doing other close work. To read by a dim light, as when one reads on into the twilight, is exceedingly injurious. A dazzling, bright light is also injurious, especially if it shines directly into the eye. In reading, one should sit so that the light will

[1] To the Teacher: A considerable proportion of the children who are regarded as dull in school fall behind their classes because of defective hearing or vision. The teacher should carefully watch his dull pupils for symptoms of trouble in the nasal passages, test the hearing by some such device as trying how far the child can hear the ticking of a watch, and note if the child holds his book close to his eyes or shows other symptoms of eye trouble. The attention of parents should be called to any defects that may be discovered, and the parents should be made to understand the importance of medical attention for such cases. Any close work is injurious to the eyes of young children, and kindergarten teachers especially should take care to see that the eyes of the children in their charge are not injured by too much sewing, weaving, or other similar work. (See also page 308, note 1.)

fall on the book, but not into the eyes. Facing a window in the daytime is injurious, and it is also injurious to read on a dark day in a corner of a room far from a window.

Reading while lying down is a bad practice, because in this position, too great a blood supply comes to the eyes, and they become congested with blood. Then, too, the book or paper is often held in a very awkward position, which strains the eyes.

Resting the eyes occasionally is very helpful. In reading, the eye is accommodated for near objects, and the ciliary muscles must be held contracted to round up the lens. In reading for long periods of time, these muscles become exhausted. It is, therefore, a good idea to stop occasionally while reading, and to close the eyes or look out of a window at a distant object, allowing the ciliary muscles to relax and rest. This advice applies of course when one is doing any work that is hard on the eyes.

Dust is exceedingly injurious to the eyes. It always causes irritation by scratching the surface of the eye and the lining of the eyelids, thus allowing the entrance of germs that may cause inflammation. For congestion and redness of the eyes, bathing in cold water is helpful. A little boracic acid dissolved in water (the exact strength of the solution is not important) and dropped into the eyes at night on retiring has a very soothing effect on the eyes, and helps to kill germs that get into them. But in any serious or long-continued trouble with the eyes, a physician or oculist should always be consulted.

Effect of Tobacco and Alcohol on the Eyes. In a few persons, tobacco affects the nerves of sight so that distinct vision and the power of distinguishing between colors are lost. Tobacco smoke is irritating to the eyes, and in a considerable

number of persons, smoking brings on a congestion and redness of the eyes and eyelids. Alcohol congests the vessels of the eyes, as it does those of other parts of the body, but the effects of alcohol and tobacco on the eyes in most cases are not very serious, as compared with their effects on some of the other organs of the body.

Summary. The eye is protected by the eyesocket, the eyelids, eyelashes, and eyebrows. It is cleansed by tears that are secreted by the lachrymal gland and are drained off into the nose by the lachrymal duct. The edges of the eyelids are kept oiled by the Meibomian glands so that the tears will not overflow on the cheeks.

The eye is moved by six muscles. It has three coats, — the sclerotic coat, choroid coat, and retina. Its interior is divided by the lens and the suspensory ligament into an anterior and a posterior chamber. The anterior chamber contains the aqueous humor; the posterior chamber contains the vitreous humor.

The transparent front portion of the sclerotic coat is called the cornea, and the front portion of the choroid coat is the iris. The iris gives the color to the eye. In the center of the iris is an opening called the pupil. The muscles in the iris open and close the pupil and in this way regulate the amount of light that enters the eye.

The lens and cornea form images on the retina of the eye. The images start impulses to the brain that give us the sensation of sight. The eye is accommodated for near and far objects by changing the shape of the lens.

It is essential to clear vision that the image fall on the retina. Eye troubles cause headaches and a derangement of the digestive and nervous systems. When spectacles are needed, they should be worn. A good light should be used

in reading, and occasionally the eyes should be rested. Dust is harmful to the eyes and tobacco and alcohol may injuriously affect them.

QUESTIONS

What is light? What does light do when it enters the eye?

How is the eye protected? Where are the lachrymal glands? the lachrymal ducts? the Meibomian glands? What is the function of the Meibomian glands?

How many muscles move each eye? Where are these muscles attached? Name the coats of the eye; the two chambers of the eye. What separates the two chambers? Where is the vitreous humor? the aqueous humor?

Of what is the sclerotic coat of the eye composed? What does the choroid coat contain? What is the cornea? iris? pupil? What is the function of the iris? How is the size of the pupil changed? Under what conditions does it enlarge and contract?

Describe the lens. How is it held in place? What is its function? Explain how an image is formed by a lens. Describe the cells in the retina and tell how nerve impulses from these cells reach the brain. What part has the brain in seeing?

Where are the ciliary muscles attached? Explain how the eye is accommodated.

What is the trouble in a near-sighted eye? in a far-sighted eye? in an astigmatic eye? in the eyes of old persons?

What effect have concave lenses on light waves that pass through them? convex lenses? What kind of lenses are needed in spectacles for near-sighted eyes? for far-sighted eyes? for astigmatic eyes?

What are some of the ailments brought on by eye trouble? Why is it important to wear spectacles when they are needed? From whom should they be procured? Mention three points that should be kept in mind in caring for the eyes. Why is dust injurious to the eyes? What effect has tobacco on the eyes? alcohol?

CHAPTER XXI

ACCIDENTS

In cases of accidents and emergencies it is often very important that something be done at once. Some of the best measures to be employed in such cases will be discussed in this chapter. When the time comes for putting these measures into use, a cool head and quick action are absolutely necessary. Therefore, at such times, keep cool, think quickly, and act sensibly and at once.

How to keep Afloat in Water. It requires very little force to keep the human body afloat in water. In trying to keep afloat, therefore, *keep your body low in the water.* A small board is enough to keep you afloat if you will do this. If thrown into the water by the upsetting of a small boat, do not try to climb upon the boat, or you may sink it. Keep your body low in the water and support yourself by taking hold of the boat with your hand. If you break through the ice, keep your body low in the water and take hold of the edge of the ice with your hand. *Every one should learn to swim,* for knowing how to swim even a few yards will often save life.

FIG. 132. Draining the water from the lungs.

How to revive a Person who has been under Water. In drowning, the trouble is that the air is cut off from the lungs by the water. The great point, therefore, *is to get air into the lungs as quickly as possible.*

The first thing is *to drain the water from the lungs.* Turn the patient on his face and lift him as is shown in Figure 132. Lift him up two or three times, jerking the body, so that all the water will come out of the lungs. Do this quickly (in about thirty seconds).

After the water is out of the lungs, turn the patient on his back. Put something — a pillow, clothes, anything at hand — under the shoulders to throw the chest out. Loosen the clothing at the neck and waist. The tongue must be drawn out of the mouth and either held or fastened by having a pin thrust through the tip. Otherwise it will drop back and close the throat. *All this must be done quickly*, for life often depends on starting respiration at once.

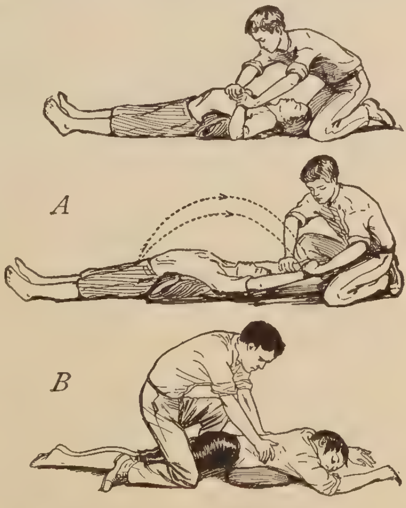


FIG. 133. Two ways of starting artificial respiration. The way shown in *B* is the better.

The next step is *to start artificial respiration.* To do this, grasp the patient's arms and pull them up far over his head (Fig. 133 *A*) while you count one, two, three. Then bring the arms down to the sides and press as hard as possible on the sides of the chest to force the air out of the lungs. Do this about twelve or fifteen times a minute. If the patient does not begin to breathe in three or four minutes, turn him over and try if any more water can be drained from the lungs.

When there are two persons to care for the patient, they should take the positions shown in Figure 134, and when the arms are brought down to the sides, one should press on the abdomen and chest in such a way as to force in the ribs and drive the abdominal organs and diaphragm upward. Keep up artificial respiration for two hours, if necessary, for persons have revived after showing no signs of life for this length of time.

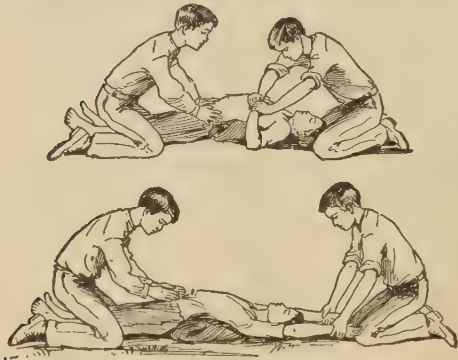


FIG. 134. Artificial respiration carried on by two persons.

A newer and better method is shown in Figure 133 *B*. About fifteen times a minute the weight of the body is thrown forward on the hands and then the pressure is removed without lifting the hands. In this method the tongue requires no care, and more air passes through the lungs than passes through them when the patient is laid on his back.

Other treatment is useful when there is help enough to give it without interfering with the artificial respiration. The limbs should be rubbed upward to make the blood in the veins flow to the heart, and, if possible, the wet clothing should be removed and the body wrapped in warm blankets. Often the easiest way of warming the patient is to pour warm water over his clothing and then cover him with a blanket. Hot-water bottles or other warm objects will help to keep up the heat. In cold weather the warming of the patient is a very important part of the treatment. After the patient begins to

breathe, he should be kept warm, the head being warmed as well as the body. Hot water or hot coffee is useful. A little alcohol or 15 drops of ammonia in one third of a glass of water every fifteen minutes is also helpful.

Suffocation. In suffocation the trouble is lack of oxygen, and artificial respiration is the remedy.

Bleeding. When a large artery is cut, the blood flows from it in spurts. When a vein is cut, the blood comes from it in a steady stream. Sometimes the bleeding can be stopped by pressing on the cut vessel with the fingers. If an artery has been cut, the pressure must be applied between the wound and the heart. If a vein has been cut, the pressure should be applied on the side of the wound away from the heart. Can you explain why this is the case? When the wound is in a limb, a handkerchief or other piece of cloth should be knotted and tightly twisted about the limb, as shown in Figure 135. The knot in the handkerchief should be placed over the cut blood vessel, and if this does not stop the bleeding, a small stone or a piece of wood should be slipped under the knot. The best place to close an artery in the leg is on the inside of the thigh, or behind the knee, because at these points the arteries can be pressed against the bones. The upper arm is the easiest place to cut the blood off from the arm. When the wound is in a part of the

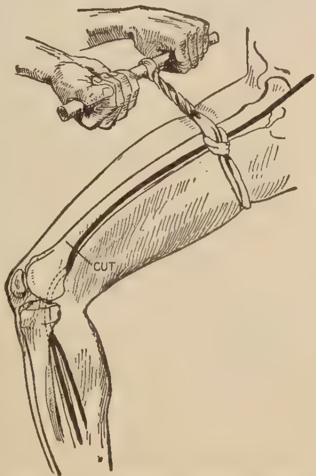


FIG. 135. Stopping bleeding from an artery in the leg.

body around which something cannot be twisted, cloths should be folded and pressed down on the wound. Any part of the body from which blood is escaping should be raised, for the blood always flows more easily to a part of the body that is lowered.

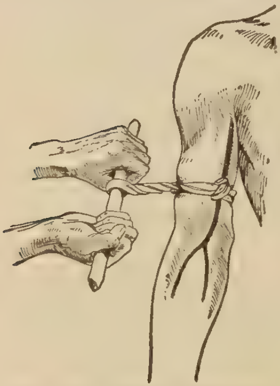


FIG. 136. Stopping bleeding from an artery in the arm.

Fainting. Fainting is caused by a lack of blood in the brain. In treating a person who has fainted, it is most important to lay him flat and loosen all clothing about the neck so that the blood can readily flow to the head. Fresh air is beneficial, and sprinkling the face with cold water or causing the patient to smell ammonia salts may assist in bringing him back to consciousness. When fainting is followed by weakness, a few drops of ammonia in a little water (15 drops of ammonia in one third of a glass of water for an adult) will prove a helpful stimulant.

Sunstroke. Lay the patient in the shade and pour cold water on or apply ice to the head, back of the neck, and spine.

Foreign Bodies in the Eye. Foreign particles may be removed from the eye by turning back the eyelid over a match or similar object, and wiping off the foreign body. The eye should not be rubbed or the particle may become embedded in the lining of the eyelid or in the outer surface of the eye. Holding up the eyelid while the eye is moved about sometimes brings the particle down to where it can be removed. Sometimes the offending body may be washed out by bathing the eye.

Burning Clothing. If your clothing should take fire, *do not start to run.* Lie down and wrap yourself in a rug, blanket, or anything you can lay hands on, to smother the flames. If no rug or blanket is at hand, lie down and roll over and over. In any case be sure and *lie down* to prevent the flames from coming up around your face, for inhaling a flame is often fatal.

When the clothing of another person is on fire, wrap him in something to smother the flames, and throw him down. Protect your own face as much as possible while doing this. In a burning building hold something before your face when near a flame.

Treatment of Burns. Moisten the clothing with water and clip it away from the wound. *Do not tear the skin.* Rather than do this, leave patches of clothing sticking to the wound. Blisters should not be broken, but the liquid in them should be drained off by making small holes with a needle in the sides of the blisters. The treatment for burns made with hct water is the same.

Shut the air off from the burn. The following are convenient methods of doing this:

Cover the wound with clean cotton cloths that have been dipped in olive (sweet) oil. If carbolic acid and glycerin are at hand, add a teaspoonful of each to a pint of the oil before it is used.

Stir baking soda into vaseline and cover the wounds with cloths on which this has been spread.

Soak cloths in water in which as much soda as possible has been dissolved, and spread them over the wound.

When nothing else is at hand, cover the wound with white of egg, wet starch, or wet flour. Do not cover a burn with cotton, or the cotton will stick to the flesh and cause trouble.

Great care should be used to keep a burn from becoming infected with germs (page 312). Unless it does become infected, it is best not to open it for some time, but to keep the cloths with which it is covered moist with sweet oil in which there is a little carbolic acid and glycerin.

Poisoning. When any poison except an acid has been swallowed, vomiting should be induced at once. To cause the vomiting, stir a tablespoonful of mustard in a glass of water, take half of it, drink a large quantity of hot water, and follow it with the remainder of the mustard. Large amounts of warm salt water or simply warm water may be used when no mustard is at hand. Tickling the throat with a feather or thrusting the finger down the throat will often bring on the vomiting.

Acids. Give soda, chalk, old mortar, or soap in plenty of warm water, and then cause vomiting. Oil and milk are also useful. For carbolic acid alcohol, oil, or milk should be used.

Arsenic. Cause vomiting and give *hydrated sesquioxid of iron.* This compound may be formed by adding tincture of iron to baking powder. Give some of the brown powder that is formed to the patient every few minutes. The poison in Paris green, Fowler's solution, and Rough on Rats is arsenic, and the treatment for poisoning with them is the same as the treatment for poisoning with arsenic.

Belladonna. This is the poison in nightshade. Use the treatment for it that is given below for opium.

Mercuric Chlorid. (Also called bichlorid of mercury and corrosive sublimate.) Give milk and white of egg or both. Flour or starch with milk and eggs is also a good remedy.

Phosphorus. Magnesia and chalk in water and the white of egg are good remedies. Do not give oil or milk. Phosphorus is in the substance on the ends of matches, and phos

phorus poisoning usually comes from allowing children to play with matches.

Opium. Give strong coffee or ammonia (15 drops in one third of a glass of water every fifteen minutes or oftener). Walk the patient about, slap him, throw cold water on him, and do not allow him to go to sleep. Morphine, laudanum, cholera mixtures, paregoric, and soothing syrups are all either forms of opium or contain it.

Strychnin. Inhaling chloroform or ether will quiet the patient. Give five grains of sodium bromid every half hour. Ammonia (see under Opium) or camphor in water is useful. Throw cold water over the patient and use artificial respiration if necessary.

Stramonium. This is the poisonous substance in Jimson weed. The treatment for poisoning with it is the same as the treatment for opium poisoning.

It is to be remembered that in poisoning with any of the above substances except acids, one of the most important things is to cause vomiting promptly. In acid poisoning it is usually best to give something to destroy the acid (page 280) before the vomiting is induced.

Summary. In accidents and emergencies a cool head and prompt action are important.

It is much easier for a person to keep afloat when his body is low in the water than when he tries to climb up out of the water. To revive a person who has been under water, the water should be drained from the lungs and artificial respiration started at once. This should be kept up for at least two hours. It is also important to keep the patient warm.

Suffocation is due to lack of oxygen, and artificial respiration is the treatment for it.

Bleeding from a large vessel may be stopped by pressing on and closing the vessel. Fainting persons should be laid flat so that the blood will flow to the head. In sunstroke the patient's head and spine should be cooled.

Running when the clothes are on fire fans the flames. In such an emergency one should lie down and smother the flames with a rug or blanket, or put them out by rolling over and over. In all cases of fire, care should be taken not to inhale the flame. In a burn the skin should not be torn, but the wound should be covered from the air.

In poisoning, vomiting to get the poison out of the stomach is a very important part of the treatment. In acid poisoning it is best to give something to destroy the acids before vomiting is caused. Other treatment should be given according to the poison.

QUESTIONS

In trying to keep afloat, where should the body be allowed to remain? What causes death in drowning? In attempting to revive an apparently drowned person, what is the important thing to do?

What is the first thing to do in attempting to revive a person who has been under water? How is this done? In what position should the patient then be laid? Why must care be exercised in regard to the tongue? Explain how artificial respiration may be carried on by one person; by two persons. How long should it be continued if the patient does not sooner revive? Describe another method that one person may use in causing artificial respiration. What is the advantage of this method? What other treatment should be given where possible?

What causes death in suffocation? What treatment should be given?

When a large artery is cut, how does the blood flow from it? How does the blood flow from a vein? Where should pressure be applied to close a cut artery? a vein? Explain how bleeding from a cut in a limb may be stopped. Where is the best place to apply pressure to shut off the blood from the leg? from the arm? How may bleeding from a cut in some other part of the body be stopped?

What causes fainting? How should a fainting person be treated? What treatment should be given in sunstroke?

What should one not do if his clothing takes fire? What are the best ways of extinguishing the flame? Why is it important to protect the face from flame?

What two important points should be kept in mind in dressing a burn? How may the air be kept from a burn?

What is an important part of the treatment in poisoning?

REVIEW QUESTIONS

CHAPTER XVI. How does the nervous system resemble a telephone system? Give the functions of the cerebrum; of the cerebellum; of the pons; of the medulla; of the spinal cord. Explain how a reflex action is carried out. Define: ganglion; neuron; afferent; efferent; convolutions; arbor vitæ; acquired reflex.

CHAPTER XVII. How many pairs of cranial nerves are there? of spinal nerves? Which roots of the spinal nerves contain the afferent and which the efferent fibers? (This may be fixed in the mind by remembering that the first letters of the words dorsal and afferent, and of ventral and efferent, spell *Dave.*) What is the function of the sympathetic system? Explain how a sympathetic reflex is carried out. How much sleep is needed by a person of your age? What are the effects of tobacco on the nervous system? of alcohol?

CHAPTER XVIII. How is alcohol formed? What is its effect on length of life? on the death rate from tuberculosis? What per cent of insanity is caused by alcohol? Give some facts that show that the evil effects of alcohol are inherited. Speak of the effects of alcohol on the character.

CHAPTER XIX. Name the special senses. How is the sensation of feeling caused? of taste? of smell? How may the olfactory cells be injured? How does a wave in the air cause a sensation of sound? Mention some ways in which the ears may be injured. Define: auditory canal; tympanic membrane; tympanum; malleus; incus; stapes; Eustachian tube; vestibule; cochlea.

CHAPTER XX. How is the eye protected? Draw a diagram of a longitudinal section through the eye. Explain how an image is formed on the retina. Explain how the eye is accommodated. What is the trouble in a near-sighted eye? in a far-sighted eye? in an astigmatic eye? In each case what kind of spectacles is needed? Mention some points connected with the hygiene of the eye.

Define: lachrymal gland; retina; vitreous humor; aqueous humor; cornea; iris; pupil; suspensory ligament; ciliary muscles.

CHAPTER XXI. Tell how to revive a person who has been under water. What should be done in cases of suffocation? of bleeding? of fainting? of sunstroke? when the clothing is on fire? in treating a burn? in cases of poisoning?

CHAPTER XXII

DISEASE GERMS

DISEASE germs cause the death of over 50 per cent of the human race. In addition to this great loss of life, they are responsible for an amount of suffering so great that it can hardly be imagined. Every year millions of dollars' worth of time is lost by persons suffering from diseases caused by germs; great amounts of time and money are constantly being spent in caring for these sufferers; and every year hundreds of thousands of people rise from beds of sickness, weakened for life by diseases caused by these small enemies of mankind.

A great part of this suffering and loss of money, time, and life is unnecessary, for germ diseases are, in the main, preventable.[1] The most useful facts of all science, therefore, are the facts that give us a knowledge of disease germs and how to avoid them.

What are Disease Germs? One-celled animals are called *protozoa* (singular, *protozoön*), and one-celled plants of a certain kind are called *bacteria* (singular, *bacterium*). The principal breeding places of protozoa and bacteria are in water and in the earth. To most kinds of them we pay no attention, for they are harmless. A few kinds, however, grow in the bodies of man and other animals, and cause sickness. When

[1] "It is within the power of man to cause all parasitic diseases to disappear from the world." — PASTEUR.

we speak of disease germs, we are referring to the little animals and plants that grow in the bodies of men and animals and cause disease.

The Multiplication of Disease Germs. All that most disease germs do when they multiply is to grow longer and pinch in two. Then there are two germs. A cholera germ may become full-grown and divide in twenty minutes, and all disease germs multiply with astonishing rapidity. If one germ and the germs that come from it should divide at the rate of once an hour, in twenty-four hours they would increase to more than seventeen millions.

Where Disease Germs come from. The germ of typhoid fever may be in water, the smallpox germ on clothes, the diphtheria germ on a pencil or a drinking cup, and the germs of many different diseases may at times be found in milk. These germs, however, do not originate in the water, on the clothes or pencil, or in the milk, but in nearly all cases *they come from some human body in which they are growing.* In the prevention of germ diseases, nothing is so important, therefore, as to keep germs from the bodies of persons who have these diseases from being scattered about.[1] The following experiments will show that disease may be spread by allowing the little plants and animals that cause them to get into new locations where they can grow:

[1] It is important to realize that germs are plants and animals, and that a germ can grow only from another living germ of the same kind. It is unsafe to have dirt and unclean matter about, only because such matter may contain germs, and any germs in it may remain alive; but the idea that germs originate in such matter is not correct. As we shall see later, a few germ diseases may occasionally be contracted from animals, and people who are not themselves sick may sometimes carry certain kinds of disease germs in their bodies. In most cases of germ diseases, however, the germ comes from another person who is suffering with the disease.

Thrust a needle into a rotten apple and then into a sound apple.[1] Lay the sound apple away for a few days and wait for the appearance of the disease in it. Cut it open and note how the rot has spread out from the needle path. The disease will probably develop more quickly if you will bore a small, deep hole in the side of the apple and pack some of the rotten material from the apple into it.

Inquire among greenhouse owners and find a carnation that is suffering from stem rot. Cut into the diseased stem, and then with the same knife cut a healthy stem half in two. Tie a cloth about the wounded stem, and keep it moist until the disease develops. The disease may be more surely produced by putting into the wound a little matter from the diseased stem.

How Disease Germs enter the Body. Sometimes disease germs enter the body through the skin, working down through the hair follicles and sweat glands, or getting into wounds. The germs of a number of diseases are introduced into the body by the bites of insects. More commonly, germs enter the mouth or nose and grow in the walls of the air passages, the walls of the alimentary canal, or in the lungs. A knowledge of how a germ enters the body often helps us to avoid the disease that it causes.

How Germs cause Sickness. When disease germs grow in the body, they produce substances called *toxins*. The toxins are very violent poisons, and cause illness by poisoning the cells of the body. You should get clearly in mind the fact that *it is not the germs themselves*, but *the toxins that the germs produce*, that cause the disease. Almost all fevers are caused by the toxins of disease germs.[2]

[1] Rots are caused by fungi (Fig. 151) that are much larger than the bacteria and protozoa that cause diseases in our bodies. The fungi are living plants, however, and closely related to the bacteria; and rots are spread by the spreading of the fungi that cause them, just as our diseases are spread by the spreading of the bacteria and protozoa that cause them.

[2] Within the body, substances called antitoxins are produced to destroy the toxins. These are discussed on page 307.

How the Body kills Germs. Germs that get into the body are killed in two ways — by the white corpuscles of the blood and by a *germicidal* (*germ-killing*) *substance* that is in the blood. The white corpuscles flow around the germs and take them in, or swallow them. Then the corpuscles attempt to digest and kill the germs, and the germs try to grow in the corpuscles and use them for food. If the corpuscles triumph, the germs will be killed and the disease

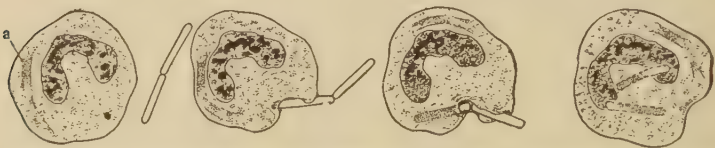


FIG. 137. A white corpuscle taking in disease germs. *a* is a germ that has been killed and partially broken up by the corpuscle.

will be checked. If the germs are victorious, the corpuscles will be destroyed, the disease will go on, and the patient will finally die.

Just what the germicidal substance of the blood is or where it comes from is not certainly known, but there is something dissolved in the blood that kills germs that get into the body. The blood of a healthy person always has some germicidal substance in it and some power of killing germs. When disease germs get into the body, more of this substance is manufactured and thrown off into the blood, where it powerfully aids the white corpuscles in the fight against the germs. The turn of the fever in germ diseases comes when the corpuscles and the germicidal substance begin to get the better of the germs.

Different Germicidal Substances. There is a different germicidal substance for each different kind of disease germ, and

after recovery from an attack of a disease, a large amount of the germicidal substance for the germ of that disease will be found in the blood. The germicidal substance for some germs remains in the blood for years, and there are many diseases that people usually have but once. This is because after an attack of one of these diseases the germicidal substance remains in the blood through life and promptly kills any germs of that kind that may get into the body. In other diseases the germicidal substances quickly disappear from the blood, and we may have them again and again.

Inherited Diseases. It is often said that diseases (*e.g.* consumption, leprosy, cancer) are inherited. By this, it is not meant that the germs of a disease are inherited, but that little power of killing those germs is inherited. If the parent has little power of killing a certain germ, the child will also be likely to have little power of killing it. The germ may get into the body of the parent, and, finding little resistance, attack him. At another time it gets into the body of the child, and the germicidal power of the blood being slight, the child is also attacked. Certain families are weak in their power of resistance to certain germs, and therefore suffer from the diseases caused by these germs. Races of men differ in their power to kill germs, the Mongolians particularly being attacked by leprosy, and the negro race having little resistance to the germ that causes consumption. The germicidal power of the body is inherited in races as well as in families, but *it is the lack of power to kill the germ, and not the germ itself, that is inherited.* A member of a family that suffers from a certain disease should take special care to keep himself free from the germs of that disease, for as long as he can keep these germs out of his body, he may be as healthy as any one.

Keeping up the Germicidal Power of the Body. The seeds of plants lie in the earth through the cold winter, waiting for the warmth of spring to enable them to grow; so disease germs often lie in the body, ready, if a favorable time comes, to start their growth. Germs capable of producing disease are usually in the body, and the germs of most dangerous diseases often enter the body at times unknown to us. The only safe way, therefore, is always to keep the body in health, so that it may be able to repel any attacks that may be made upon it. Overwork, hunger, exposure to cold, wet feet, insufficient sleep, bad ventilation, bad food, lack of exercise, alcohol — all of these things injure the body and lower its germicidal power. It is a duty that every one owes to himself to keep his body in good condition, and to fail to do so is no more sensible than it would be for a garrison in a hostile country to go to sleep with the gates of the fortress open.

Alcohol and Germ Diseases. We have already learned that the world's greatest authorities on tuberculosis state that alcohol drinking renders the body more susceptible to the germ that causes that disease (page 240). Physicians have observed that a drunken spree sometimes brings on an attack of pneumonia, and it has long been the opinion of medical men that alcohol drinkers are more liable to the attacks of germ diseases than are non-users of alcohol.

More recently it has been definitely proved by experiments on animals that alcohol lowers the germicidal power of the body, and it has been discovered that alcohol paralyzes the white corpuscles and renders them unable to take up and destroy disease germs. Knowing this, it is easy to understand why drinking may bring on an attack of a germ disease. When pneumonia germs are already in the body waiting for

a chance to attack it, and the white corpuscles are paralyzed by drinking alcohol, we need not be surprised if the disease develops.

Summary. Disease germs cause the death of over one half of the human race. They are small plants and animals that grow in the body and multiply with great rapidity. They are spread from the bodies of those who are suffering with germ diseases, enter the body in various ways and cause disease by producing a poisonous toxin.

The body kills germs by its white blood corpuscles and by a germicidal substance in the blood. The germicidal substance is increased during an attack of a disease, and after recovery may remain in the blood, so that the person will be protected against that disease for life. Certain families and races of men are particularly weak in their power to kill certain germs. It is of the greatest importance to keep up the germicidal power of the body. This is lowered by alcohol.

QUESTIONS

What are disease germs? How do they multiply? Where do the germs that cause our diseases come from? How do they enter the body? How do they cause sickness? How does the body kill them? Why do we usually have certain diseases only once? What is meant by an inherited disease? Why is it important to keep up the germicidal power of the body? Mention some ways in which the resistance of the body to germs may be lowered. How does alcohol reduce the power of the body to kill germs?

CHAPTER XXIII

DISEASES CAUSED BY PROTOZOA

The protozoa (page 285) are the smallest of all animals. The largest of them can barely be seen with the naked eye, and under the most powerful microscope the smallest of them look like tiny specks. Some of those living in the ocean have shells, and so abundant are they that great beds of chalk and limestone are built by them. Others are phosphorescent, and in the warmer seas the waves at night are often fringed with light from the multitude of protozoa in the water. They are abundant in fresh water also, every pool and puddle containing great numbers of them, and they grow as parasites in almost every animal from worms and insects up to man. Some of our worst diseases are caused by protozoa.

MALARIA

Malaria is one of the worst diseases that afflict mankind. No community or portion of a country can reach its highest state of development as long as malaria is prevalent in it; for the disease affects a large number[1] of the inhabitants, and persons so affected do not have and cannot have the strength, energy, and ambition necessary to carry on great

[1] In malarial countries the germ is sometimes found in the blood of from 20 to 30 per cent of the inhabitants. In many instances the disease takes a slow chronic form in which the patient does not have chills and fever, and often does not know that he is suffering from the disease. The germ may remain in the body for years.

enterprises. Many of the most backward portions of our country would in a very few years be centers of industry, education, and leadership, if malaria could be eradicated from them.

The Cause of Malaria. Malaria is caused by protozoa that live in the red corpuscles of the blood. The protozoön increases in size until it almost fills the corpuscle. Then it divides into a number of parts, each of which is a young germ. These break out of the corpuscle into the blood, and then each one settles upon and enters a fresh red corpuscle. Within the corpuscle the germ grows and the young break forth in due time to repeat the process.

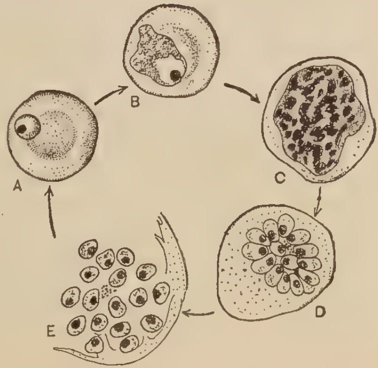


FIG. 138. The malaria germ in a red blood corpuscle. *A*, *B*, and *C* show the growth of the germ; *D* shows it dividing into a number of young germs; *E* shows the corpuscle broken down and the young germs escaping into the blood.

During their growth within the corpuscles the malaria germs produce toxin. At the time when the young break down the corpuscles and come out into the blood, a great amount of this toxin is liberated in the blood at once, and the result is a chill and fever. In addition to injuring the body with its toxin, the malaria germ destroys millions of the red blood corpuscles, thus interfering with the oxygen-carrying power of the blood.

Kinds of Malaria Germs. There are several different varieties of the malaria germ, some of which produce a more

severe form of the disease than others. In one form of the disease the germ requires seventy-two hours to complete its growth and break out of the corpuscles. In this kind of malaria, the chill comes every third day. In other forms, the germs require forty-eight hours for their development, and in these kinds of malaria the chill comes every other day. It is quite possible, however, to have more than one crop of the germs in the blood at one time. One set of germs may break out of the corpuscles one day and a different set the next day, so that the affected person may have a chill every day. In some cases of malaria the germs may keep coming out all the time and the patient may have a continuous fever. Usually a malarial fever rises and falls, and for this reason a continuous malarial fever is often called remittent fever.

How the Malaria Germ enters the Body. The malaria germ is introduced into the body by a certain species of mosquito (Fig. 152). A mosquito feeds on man by inserting its proboscis through the skin and sucking out the blood. When a mosquito draws blood from a person who is affected with malaria, it takes malaria germs into its stomach. The germs enter the wall of the mosquito's stomach, and multiply there, and many of them finally reach the mosquito's salivary glands.

The opening in the proboscis of a mosquito is too fine to allow red blood corpuscles to pass through it. The mosquito, therefore, when it thrusts its proboscis through the skin to feed, injects saliva down through its proboscis into the wound to break up and digest the red corpuscles. If the mosquito is infected with malaria, the germs will be injected into the wound with the saliva. The germs thus introduced into the body enter the red blood corpuscles, and about a week later the disease develops.

Curing Malaria. After the germs of most diseases get into the body, it is impossible to kill them by taking medicines. The germs are harder to kill than our own cells, and we cannot poison them with medicines without poisoning our own bodies. Fortunately, the human body can endure an amount of quinine that will poison and kill the germ of malaria.[1] Malaria is, therefore, one of the few germ diseases that can be successfully treated by taking medicine to kill the germ. It is far better, however, to prevent the disease than to try to cure it.

The Prevention of Malaria. Man gets the malaria germ from the mosquito, and the mosquito gets it from man. If we could destroy all mosquitoes, the disease, of course, would die out. If we could destroy all the germs that are in the blood of malaria patients, the mosquitoes would not become infected, and the disease would cease to be spread. The following suggestions for the prevention of malaria are in accordance with these principles, and by following them out much can be done to check the disease:

Screening Malaria Patients. It is very important to keep a malarial patient under mosquito netting until the germs disappear from his blood. Where this is not done, it has been found that the mosquitoes in the house become infected by biting him, and that other persons in the house usually contract the disease. In regions where there is only an occasional case of malaria, or where only a few persons are living close together (as in a country farmhouse), this precaution will do much to prevent the spread of malaria.

Avoiding Unnecessary Exposure to Mosquitoes. Persons

[1] Malaria germs are killed much more easily by quinine while they are free in the blood than when in the corpuscles. The quinine should be taken so that it will be in the blood at the time when the germs come out of the corpuscles.

living in malarial regions should keep their houses carefully screened and should sleep under mosquito nets during the mosquito season. They should not expose themselves to the attacks of mosquitoes very early in the morning or late in the day, and should take care to avoid the haunts of the mosquitoes on cloudy days when mosquitoes are flying. Judgment should be exercised in selecting places to be visited in camping and fishing excursions, for one night spent among mosquitoes may start an attack of malaria that will last for months.

The Use of Quinine. Quinine frees the blood from malaria germs, and thus prevents mosquitoes from becoming infected. A little quinine in the blood will also kill any malaria germs that may be introduced into the body by an infected mosquito, and thus prevent the development of the disease. In malarial regions it is sometimes advisable to take small doses of quinine daily as a preventive measure.

Destroying Mosquitoes. This is the most effective of all the measures that are employed in fighting malaria. The subject will be discussed in a later chapter (page 323).

FIG. 139. The ameba of dysentery. The three dark bodies within the ameba are red blood corpuscles on which it has been feeding.

DYSENTERY

Chronic dysentery is usually caused by a protozoön, an *ameba*, that is similar in many ways to a large white blood corpuscle. The disease is most common in the tropics, but is found in our own country. The ameba of dysentery lives in water, and when swallowed, enters the wall of the large intestine and grows there. The disease comes from impure water, and the best methods of preventing it will be taken up in another chapter.

SMALLPOX

Smallpox is probably caused by a small protozoön that lives in the cells of the skin and of certain other parts of the body.[1] The germs may be carried on clothing or anything that a smallpox patient touches, and there are great numbers of germs in the dried scales that come from the skin during recovery from the disease. As smallpox germs may remain alive for months after being dried and scattered, the disease is very easily spread. For this reason a person suffering from smallpox should be quarantined, and everything that has been about him should be burned or disinfected (page 332). The incubation period of smallpox (the time between the entrance of the germs into the body and the appearance of the disease) is usually from seven to twenty-one days.

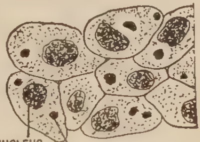


FIG. 140. The germs of smallpox in the cells of the skin.

Vaccination. Before vaccination was discovered, smallpox was one of the hardest of all diseases to control. Up to a little over one hundred years ago, about 95 per cent of all persons were attacked by it, and the number of deaths from smallpox was enormous. About the year 1800 vaccination began to be practiced, and in all civilized countries it is now more or less compulsory. Where vaccination is thoroughly carried out, smallpox has almost ceased to exist, but in countries where the people are not vaccinated, or where only part

[1] There is still some uncertainty in regard to the germ of smallpox, some of those who have studied the bodies shown in Figure 140 holding that they are not the germs that cause the disease. It is certain, however, that smallpox is a germ disease, and we have learned how to control it even if we are not certain as to the exact germ that causes it.

of them are vaccinated, it is still impossible to prevent the spread of the disease.[1]

How Vaccination protects against Smallpox. The germ of smallpox flourishes in man. It grows in cattle also, causing the disease called cowpox. After growing in the cow this germ seems to be weakened and changed so that it grows feebly in man and has only a slight power of producing disease.

In vaccination, germs from a cow are put into the human body. Here they grow and begin to produce the mild inflammation that follows vaccination. The body now works up the germicidal substance for these germs and kills them out before they can make much growth and spread through the body. After this is done, the germicidal substance remains in the blood, and if any smallpox germs get into the body, the germicidal substance is there to kill them.

From this you will understand that a person who has been successfully vaccinated is in very much the same condition as a person who has had a light attack of smallpox. After

[1] In the United States, Canada, and the other countries with which we are most familiar, vaccination has been extensively practiced and in consequence in these parts of the world smallpox has been rare and most cases of it are mild. Because of this fact, many persons have come to believe that it has lost its old-time malignancy. This notion is incorrect, as is shown by the history of smallpox in other parts of the world in recent times. From 1893 to 1898, Russia had over 275,000 deaths from the disease, Spain nearly 24,000, Hungary over 12,000, and Italy and Austria each over 11,000. Before the American occupation of the Philippine Islands, only a part of the inhabitants of the Islands had been vaccinated, and thousands of deaths from smallpox occurred every year. The people have now been thoroughly vaccinated, and in 1907 there was not a single death from the disease in seventeen provinces of the Islands. There is no doubt that the decrease in the death rate is due to vaccination, for quarantining has failed to prevent a considerable amount of certain other diseases (diphtheria, scarlet fever, etc.) that are much less infectious than smallpox.

vaccination, as after recovery from an attack of many germ diseases, the germicidal substance in the blood becomes weaker and weaker, but never entirely disappears. Just when it becomes so weak that revaccination is necessary, it is impossible to say. A successful vaccination usually protects from smallpox for several years. Sometimes the germicidal substance in the blood is fairly strong after seven, eight, nine, or ten years. Two successful vaccinations usually protect against smallpox for life, but in a very few persons the germicidal substance disappears so rapidly after vaccination that the disease may be contracted in nine months. The safest way is to be vaccinated every few years, and when smallpox is prevalent, to be revaccinated if more than nine months have passed since the last vaccination. There can be no mistake in this, for if the germicidal substance is still strong in the blood, all the germs put in by vaccination will be killed, and the vaccination will not take. If the vaccination does take, it is a sure sign that the germicidal power of the body had run low and that revaccination was needed.

RABIES (HYDROPHOBIA)

Rabies is believed to be caused by a protozoön that grows in the nerve tissue. This germ attacks not only man, but also many of the lower animals. It is found in the saliva of animals suffering from the disease, and usually gets into the human system through the bites of rabid animals. Practically all the rabies in our country comes from the bites of dogs, and it would be possible by properly muzzling dogs to stamp out the disease entirely, as has been done in several European countries. It is a mistake to think that rabies develops in dogs because of hot weather, for they get the

germ from the bites of other dogs and may have the disease at any time of the year.

In man the germ of rabies grows very slowly. At least two weeks are required after the germs are introduced into the body before the disease shows itself. Usually the disease does not develop for five or six weeks, and sometimes not for a year. There is no cure for rabies after the disease develops, but a preventive treatment, founded on the same principles as vaccination, was discovered by a great French scientist named Louis Pasteur. The Pasteur treatment is successful in nearly all cases in which it is commenced in time. Where the materials for this treatment can be delivered within thirty-six hours, they can be sent by mail and the treatment given to the patient by his home physician. No time should be lost in beginning the treatment.

The Treatment of Wounds made by Rabid Animals. A very great safeguard against this disease is to treat promptly wounds made by the teeth of animals with something that will kill the germs in the wounds. Any disinfectant (page 334) is useful, but burning with nitric acid is the most effective remedy. This should be done by a physician to make sure that it is thoroughly done, and to guard against too great injury to the flesh by the acid. The best method is to apply at once to the wound any disinfectant that may be at hand and then have it treated as soon as possible by a physician. Treatment of the wound even after twenty-four hours is useful. An animal that has bitten any one should not be killed, but should be confined until it is known whether or not it has hydrophobia. If the animal remains in health for nine or ten days, there will then be no occasion for worry.

Other Protozoan Diseases. In the tropics many diseases of man are caused by protozoa. Among these diseases are the

slow and fatal sleeping sickness of Africa, which is communicated to man by a fly. It is thought that scarlet fever, measles, and yellow fever may be caused by protozoa, but the germs of these diseases are not known. Rocky Mountain or "spotted" fever, a disease of the Rocky Mountains, which is caused by the bite of a tick, may also be a protozoan disease. A protozoön that is carried by a tick causes the "Texas fever" or "tick fever" that is prevalent among cattle in our Southern states, and in the tropics many fatal diseases of animals are caused by protozoa.

Summary. Protozoa cause many diseases of man. Among them are malaria, dysentery, and perhaps smallpox, and rabies. Malaria germs are carried by mosquitoes, and the disease may be escaped by avoiding mosquitoes. Dysentery usually comes from impure water. The germ of smallpox is easily spread, and few persons naturally have the power to resist it. By vaccination the germicidal power of the body toward the smallpox germ may be raised and the disease controlled. Rabies comes from the bites of dogs. Generally the disease can be prevented from developing by the Pasteur treatment. Wounds made by the teeth of animals should be disinfected. Protozoa cause other diseases of animals and men.

QUESTIONS

Why is malaria an important disease? Describe the life history of the malaria germ. What causes the chill in malaria? How does the malaria germ enter the body? How long is it after the germ gets into the body before the disease appears? How may the malaria germ be killed in the blood? How may malaria be prevented? Where does the germ of dysentery grow in the body? How

does it get into the body? How may smallpox germs be spread? What is the incubation period of the disease? What per cent of people had smallpox before vaccination was practiced? Explain how vaccination protects the body. How often should one be vaccinated?

How does the germ of rabies enter the body? How may the disease be stamped out? What is the incubation period of rabies? How may the development of the disease be prevented? How should wounds made by the teeth of animals be treated? Name some other diseases that are thought to be caused by protozoa.

In some parts of our country there is no malaria. Why is this the case? Sometimes persons who have been living in a malarial region have chills and fever when they move into a region where there is no malaria. In such cases, where do the germs come from that cause the disease? People sometimes have chills and fever in the winter or spring when no mosquitoes are flying. Where do the malaria germs come from in these cases?

When persons who have been vaccinated take smallpox, they usually have a light attack of the disease. Why should you expect this to be the case? Ask a physician to explain to you the Pasteur treatment for hydrophobia. How does the principle underlying this treatment resemble the principle on which vaccination is founded?

With a microscope examine a drop of dirty water for protozoa.

CHAPTER XXIV

DISEASES CAUSED BY BACTERIA

Bacteria are so extremely small that millions of them have plenty of room to swim about in a drop of water, and a drop of sour milk commonly contains about fifty million bacteria. It would require twenty-five thousand of them, placed side by side, to make a row an inch long. Examined under a microscope that would cause a man to appear as high as Mount Washington or Mount Mitchell, bacteria look about as large as the periods and commas in ordinary print. So exceedingly small are these little plants that they can pass through the pores in a brick as easily as a man passes through the doorway of a house.

Another remarkable thing about bacteria is their power of multiplication. It has been calculated that if all the bacteria in the world could get food, warmth, and moisture so that they could multiply as fast as they are capable of doing, in two days they would fill all the oceans and cover all the land fifty feet deep. Fortunately for us, most of them are held in check by lack of the right conditions for growth. Yet they show what they can do when they get into such favorable places as warm milk; for a quart of milk, before it sours and thickens, usually contains eight or nine hundred billions of bacteria.

The Distribution of Bacteria. Bacteria are everywhere about us — in the water, in the soil, and clinging to the small

particles of matter that are always floating about in the air. About three million bacteria are ordinarily found in an ounce of cultivated soil, and they are much more abundant than this in the earth around houses and barns. The water from most wells contains more than one million bacteria to the quart. Millions of bacteria are always growing on the human skin, and in the mouth, the intestine, and the respiratory passages. Some kinds of bacteria are useful; most kinds are harmless, and to them we pay no attention; but a few kinds produce toxins in the human body that cause some of our worst diseases.

Shapes of Bacteria. Bacteria are cylindrical, spherical, or spiral—shaped like a firecracker, a marble, or a corkscrew. The cylindrical bacteria are called *bacilli* (singular, *bacillus*). The spherical bacteria are called *cocci* (singular, *coccus*), and the spiral forms are called *spirilla* (singular, *spirillum*). The shapes of bacteria have nothing to do with the diseases which bacteria cause, but often give a convenient way of distinguishing between different kinds.

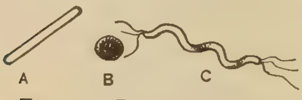


FIG. 141. Bacteria. *A* is a bacillus, *B* is a coccus, and *C* is a spirillum.

BACTERIAL DISEASES OF THE RESPIRATORY ORGANS

Diphtheria. The diphtheria germ grows usually in the pharynx, but is also commonly found in the larynx and mouth, is sometimes found on the lips and in the nose, and may grow in other parts of the body. It does not usually grow outside of the human body, but it can remain alive for several weeks in matter that has come from the throat of a diphtheria patient. On slate pencils that have touched the

lips of a person who has diphtheria, living diphtheria bacilli have been found for several days. The incubation period of the disease is usually from two to seven days, but may be less.

Sometimes attacks of diphtheria are so severe that death comes in a day or two. In other cases, the germs make only a slight growth before the body gets the upper hand of them, and the attack is so light that it is often mistaken for a simple case of sore throat. In still other cases, the diphtheria bacillus lives in the throat without causing illness at all.[1] Where the germs remain in the throat without causing sickness, the body is able to hold them in check and keep them from making enough growth to harm it, but is not able to kill them out entirely. After recovery from an attack of diphtheria it is not uncommon for virulent germs to be found in the throat for four or five weeks, and in one case they were found eight months after recovery from the disease. The disease called membranous croup is the same as diphtheria.

FIG. 142. The diphtheria bacillus.

How Diphtheria is contracted. Diphtheria is usually contracted by getting the germs on the hands and then from the hands into the mouth. Sometimes germs that have been coughed out into the air[2] are inhaled. Dried sputum

[1] Most healthy persons who have the diphtheria germs in their throats have been about some one who is suffering from the disease.

[2] In coughing, sneezing, laughing, and to a certain extent in talking, small droplets of liquid are sent out into the air. These may fly to a distance of three feet, and some of them are so very fine that they are said to float in the air for as long as twenty minutes. When a person is suffering from a disease like diphtheria, pneumonia, or consumption, these droplets are of course filled with the germs of the disease. One should not stand near a person who is coughing, and a sick person should hold a handkerchief before his face when he coughs.

may contain living diphtheria germs, but dust is not an important carrier of the disease. The germs are almost certain to get on the handkerchiefs and hands of persons having the disease. They may be left on a drinking cup or on a pencil, on a toy or a piece of candy that has been handed about among children, and in many other ways they may be transferred from one person to another. They sometimes get into the body from milk (page 330) and they are often carried by flies and left where they reach the respiratory passages.

Quarantining in Cases of Diphtheria. The diphtheria germ is sometimes found in the throats of healthy persons, in the throats of diphtheria patients who have long since recovered from the disease, and in mild diphtheria cases where the disease has not been recognized. Persons are therefore going about who are themselves perfectly well, or at least only slightly ill, but who nevertheless carry diphtheria germs that are exceedingly dangerous to others. These persons often object to being quarantined, and health officials have great difficulty in preventing the spread of diphtheria. The only way by which the disease can really be controlled is to shut up in quarantine every one who has virulent diphtheria germs in his throat, whether or not he is himself ill. This often involves quarantining for long periods of time both diphtheria patients and members of families in which there is diphtheria.

Diphtheria Toxin and Antitoxin. The diphtheria germ may cause death by closing the throat, but usually the cause of death is the very powerful *toxin* which the germ produces. This toxin attacks the nervous and the muscular systems, and the direct cause of death often is that the nerve and muscle cells of the heart are so injured that the heart stops.

We have already studied about how, when germs get into

the body, the body begins to work up its power of killing them. So when toxin is produced in the body, the body works up a substance called *antitoxin* that neutralizes, or destroys, the toxin. If the body can produce enough antitoxin to keep the toxin from poisoning the cells, the germicidal power of the blood will rise, and finally the germs will be killed out. But if the toxin is not destroyed, it will poison the body and take away its power of killing germs, the bacteria will triumph, and death will come. *The antitoxin does not kill the germs*, but protects the body from the toxin until the white corpuscles and the germicidal substance in the blood can overcome the germs.

The Antitoxin Treatment. It was found that the horse has a very great power of producing antitoxin, and the antitoxin now constantly used in the treatment of diphtheria is secured from the horse in the following way:

Diphtheria germs are placed in beef broth, where they grow and multiply, and produce great amounts of toxin. A little of this toxin is then injected into the blood of a horse, and the horse works up antitoxin to destroy it. Then a larger dose of toxin is given the horse, and still more antitoxin appears in the blood. This is kept up until the blood is made as strong in antitoxin as possible. Then the horse is bled, and the blood allowed to coagulate, or clot. The thin, yellowish serum that appears around the clot contains the antitoxin, and it is this which is placed in sealed bottles and sold as antitoxin after it has been freed from certain slightly injurious substances which it contains.

When a person has diphtheria, and the germs begin to manufacture toxin and poison the cells, some of the antitoxin from the horse is injected into the blood. This unites with the toxin and saves the body cells from being poisoned, thus

giving the body time to kill the germs and so stop the disease. When antitoxin is used in the early stages of diphtheria, practically all deaths from this disease are prevented. But it is very important to use it before the toxin has poisoned and destroyed the cells. Antitoxin is often given as a preventive to those who have been exposed to the germs.

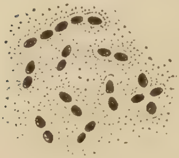


FIG. 143. The pneumonia germ.

Pneumonia. In some of the Northern states pneumonia leads even tuberculosis as a cause of death. It may be due to any germ that grows in the lungs, but it is usually caused by a small coccus (*Pneumococcus*). This germ causes not only pneumonia, but also colds, inflammation of the middle ear,[1] and meningitis (page 317). The germs are in the secretions from the mouth and nose, and they are transferred from one person to another in the same manner as the germs of other respiratory diseases.

Recent studies indicate that one very important method of infection in all the saliva-borne diseases is through the eating utensils and glasses in public eating places and in soda fountains and ice-cream parlors. In certain army cantonments and among the workers in a number of public eating places investigated, there was, during a given time in the 1918 epidemic, less than one fifth as much influenza where the dishes were washed with boiling water as where they were washed by hand.

[1] Inflammation of the middle ear is caused by many different kinds of germs. It is very serious, for incurable deafness will follow the breaking down of the chain of bones, and there is danger of the inflammation spreading. Sometimes the germs get into the cavities that are in the bone above the middle ear (Fig. 119), producing the disease called *mastoiditis*, and sometimes they work through into the cranial cavity and cause meningitis, or a brain ulcer. Running ears and other diseases of the ear from which children especially suffer should not be neglected.

Varieties of the Pneumonia Germ. There are many different varieties of the pneumonia germ. Some of these are exceedingly virulent; some are perhaps not dangerous at all. Three races, or types, that are responsible for about 80 per cent of all pneumonia cases and 90 per cent of the deaths from the disease are now distinguished. A serum that is useful in treating cases due to one of these races is now used.

Preventing Pneumonia. Perhaps the most important measure in the prevention of pneumonia is the isolation of cases of the disease. Many healthy persons are carriers of germs of the milder races, but the virulent kinds are not widespread.

A second important factor in the prevention of pneumonia is rest in bed when attacked by colds, influenza, and measles. Many cases of pneumonia begin as colds, the germs later working downward into the lungs, while nearly all deaths in connection with measles and influenza are due to pneumonia following these diseases.

Anti-pneumonia vaccination has been tried with very encouraging results in the United States Army, and some health officers advise every one to be vaccinated against the pneumonia germ. This is done by injecting killed cultures of the germ beneath the skin, as is done in vaccination against typhoid fever.

Avoiding undue fatigue and exposure to cold and wet are other important means of keeping up the body resistance to the pneumonia germ.

Influenza. It was formerly believed that the cause of influenza is a small bacillus found in many cases of the disease, but investigations made during recent epidemics indicate that probably it is due to an undiscovered germ. It is supposed that the germs pass from one person to another in the secretions from the mouth and nose. The disease is a dreaded

one, because so many persons are attacked and because of its severity and the danger that pneumonia will follow it.

FIG. 144. The bacillus that was formerly believed to be the cause of influenza.

Influenza is one of the most easily communicable of all diseases. Good health and physical vigor give no immunity, and one attack does not protect against another. Medical authorities are agreed that a person with influenza should go to bed at once and remain in bed until he is thoroughly recovered. This not only lightens and shortens the influenza attack, but it greatly reduces the risk of pneumonia, which is the chief danger with the disease.

Colds. Many different kinds of germs (the pneumonia germ among them) are found in the respiratory passages of those who have colds. It is probable, however, that the primary cause of epidemic colds is a germ that is as yet undiscovered, and that the bacteria found in the respiratory tract are secondary invaders that appear after the tissues have been weakened by the first germ. Against epidemic colds no protection is known except keeping away from those who have them. Care of the health, the removal of adenoids and diseased tonsils, and the remedying of nasal defects are important in the treatment of chronic colds.

Whooping Cough. Whooping cough is caused by a bacillus that grows in the trachea and bronchial tubes. About 10,000 deaths are due to it each year in the United States. It is especially severe in small children, and great care should be exercised to protect children under five years of age from it. By vaccination the disease can in some cases be prevented, and in other cases the vaccination usually shortens the course of the disease and lessens its severity.

Consumption. Consumption is so important a disease that it will be discussed in a separate chapter (chapter XXVI).

DISEASES CAUSED BY BACTERIA THAT ENTER THE BODY THROUGH THE SKIN

The Pus-forming Bacteria. Several different kinds of bacteria are included in this group. They are found in earth around the habitations of men and animals and in polluted water, and are always found on the human skin, where they feed on the dead cells and other matter on the skin. When they grow in the tissues, they cause inflammation and form *pus*, or the thick liquid matter that is found in boils and infected wounds.

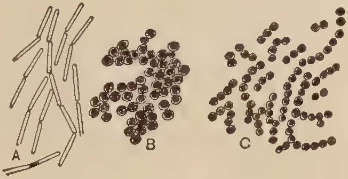


FIG. 145. Three pus-forming bacteria. *A* causes the bluish-green pus sometimes found in wounds; *B* is the most common cause of boils; and *C* causes erysipelas and often is the cause of boils and of blood poisoning.

Diseases caused by the Pus-forming Bacteria. The pus-forming bacteria cause boils, carbuncles, erysipelas, blood poisoning, and inflammation in wounds and sores. They may also cause inflammation in the internal parts of the body. Tonsillitis and appendicitis are usually caused by these germs, and meningitis may be caused by them. It thus appears that the same germ that makes a wide-spreading growth in the skin and causes erysipelas, can make a deep, localized growth and cause a boil or carbuncle, spread through all the body and bring on blood poisoning, or produce meningitis by growing in the membranes and fluid around the brain and cord. The pus-forming germs found in cases of erysipelas and abscesses are often very malignant, and care should be used to prevent their spread.

The Pus-forming Germs Injurious to the Body. A strange idea that is very prevalent is that boils are beneficial to us. Probably this belief arises from the fact that so much offensive matter comes from a boil. It is exceedingly important to open up infected wounds, boils, and carbuncles, and get the matter in them out of the body, for it is injurious and dangerous to allow it to be carried through the body by the blood. The pus, however, is composed chiefly of germs, dead tissue cells, and dead white corpuscles which the germs have killed. It no more benefits the body to have pus-forming germs kill patches of the tissue and poison the whole system with their toxins than it benefits the body to have diphtheria, typhoid, or any other disease germs in it

Care of Wounds. For our protection against pus-forming germs, it is very important to know how to care for small wounds. If the wound has been made by a clean instrument, and bleeds freely, the blood will wash the germs outward, and by its germicidal power will probably kill any bacteria remaining in the wound. In such a case, the best thing is to tie the wound up "in the blood," and not open it until it is healed, unless inflammation sets in. A good plan is to wrap the wounded part in a thin, clean inner cloth, and outside of this tie a second cloth. The outer cloth can be changed from time to time when it becomes soiled, while the inner cloth is left undisturbed to keep germs from getting into the wound.

When a wound has been made with anything unclean, it should be washed with a disinfectant (page 335) to kill germs in it, before it is tied up. After being bandaged, a wound should be carefully watched, and if pain, redness, and swelling show that germs have got into it, it should be opened at once and disinfected. A salve containing carbolic acid is

very useful in dressing small wounds and sores, because the carbolic acid kills germs. Turpentine is an excellent agent with which to treat a wound, and one that is often at hand.

Rheumatism. Acute rheumatism is a germ disease. Some think that it is caused by pus-forming bacteria growing in the joints, and others hold that it is caused by a very tiny germ of its own. When this disease attacks the valves of the heart, it is often fatal.

Tetanus (lockjaw). Tetanus is caused by a bacillus that is commonly found in the earth about dooryards and gardens, in the dust of streets, and in great abundance about stables where horses are kept. It affects chiefly man and the horse and gets into the body through wounds, often through wounds so small and insignificant that no attention is paid to them. The tetanus germ by itself cannot grow except when it is shut off from the air. With other germs, however, it can grow in an open wound.

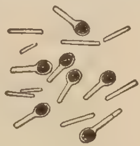


FIG. 146. The bacillus of tetanus.

The tetanus bacillus grows especially in wounds made by unclean instruments, because such wounds are likely to be infected with this germ, and because pus-forming germs and particles of dirt are left in such wounds. It grows best of all in small, deep wounds like those caused by an unclean nail, because wounds of this kind readily close over and leave the tetanus germ with other germs and foreign matter buried deep in the flesh and away from the air. The percussion caps used on toy pistols also make dangerous wounds. The germs are in the dust on the skin, and the very small, sharp, flying particles of the caps cut deep into the flesh and drive down tetanus germs along with other bacteria and dust.

The bacillus of tetanus is so common that it undoubtedly

gets into many wounds in which it never grows, but it is always wise to look after and protect every wound. Wounds made by unclean instruments should be carefully sterilized, and wounds on the feet of barefooted children should receive special attention, because these come in contact with the earth and are exposed to infection. Wounds of a kind that are especially liable to cause the development of the disease should be looked after by a physician.

The Toxin of Tetanus. The tetanus germ makes only a very slight growth in the body, but it produces a toxin of tremendous power. This toxin for man is a poison nineteen times as strong as dried cobra venom, and two hundred and fifty times as strong as strychnin. It produces its effects by poisoning the nervous system, and through this so affects the muscles that they are all thrown into contraction. The muscles of the jaw, esophagus, and neck are often affected before the other muscles in tetanus.

Tetanus Antitoxin. An antitoxin for tetanus has been prepared, but this is successful only when used in large doses very soon after the disease develops. It is very useful, however, in preventing tetanus, and when a person has received a wound that is likely to bring on this disease, many physicians make a regular practice of giving a dose of tetanus antitoxin to keep the disease from developing.

Leprosy. Leprosy is caused by a slow-growing bacterium, similar in some ways to the tuberculosis germ. It produces little toxin, and may exist in great numbers in the tissues of the body for years before death results. Leprosy is slightly contagious, though not so contagious as consumption. It is believed that a cure for leprosy has been discovered.

Bubonic Plague. Bubonic plague is the disease that was called the Black Death in the Middle Ages. In 1907 there

were 860,000 deaths from it in India. It is caused by a bacillus that attacks rats and mice and gets into the bodies of men from fleas that have lived on infected animals. The disease is carried from one country to another by sick rats, and the way to fight it is to destroy the rats. It is now in all the continents, and our seaports are in constant danger from it.

BACTERIAL DISEASES OF THE ALIMENTARY CANAL

Typhoid Fever. This disease is caused by a bacillus that is taken into the body through the mouth. Usually it is a very severe disease, and often it leaves the sufferer weakened in some organ for life. But sometimes an attack of typhoid fever is so light that the patient does not realize that there is much the matter with him. The excretions from the intestines and kidneys of a typhoid patient are filled with the germs.[1] These germs can live in water and in refuse matter outside of the body, but if they are dried, they die in a short time. By vaccination with dead germs typhoid fever can be almost entirely prevented, and the discovery of this fact has helped greatly in controlling the disease.

FIG. 147. The bacillus of typhoid fever. This germ is fitted for life in the water and swims actively.

How Typhoid is contracted. Since the typhoid germ dies from drying, it is not carried about in the air, but must get

[1] About one person in every thirty who has typhoid fever carries the typhoid bacillus through life. The germs remain in the gall bladder and intestine without seeming to affect the person in whom they are growing A cook in New York City infected twenty-six persons in a period of five years, and the germs have been found in the excretions from the body forty-two years after recovery from the disease.

to the mouth without being dried out. Persons in the same house with a typhoid patient may contract the disease from the dishes, by getting the germs on the hands, from handling the bedding, or in any of the many ways by which it is possible for such small bodies as bacteria to be carried about. Flies will carry the germs about in great numbers, if all wastes from typhoid patients are not carefully destroyed. Occasionally the germ is in oysters that have been grown in polluted waters, and for this reason, cooked oysters are safer than raw oysters. In a large number of cases, the typhoid germ has been carried in milk where some one having the disease had prepared or handled the milk,[1] or where the milk vessels had been washed in water containing the germs. If a single typhoid germ should get into a can of milk, it could produce thousands or perhaps millions of germs before the milk was used, so the milk supply must be carefully watched. In a great many cases, however, typhoid is contracted direct from water. In the next chapter we shall discuss the subject of disease germs in drinking water.

FIG. 148. The cholera germ.

Cholera. Cholera is caused by a germ that grows with great rapidity in the intestines, and produces a strong toxin, sometimes causing death within a few hours. Like the typhoid germ, it gets into the alimentary canal through water and foods.

Other Bacterial Diseases of the Alimentary Canal. There is a group of germs closely related to the typhoid germ that cause intestinal diseases. The worst of these are the germs that cause so much sickness among small children during the summer months (Appendix).

[1] In the spring of 1908 one milkman in Boston who was suffering from typhoid caused an epidemic of about 400 cases.

OTHER BACTERIAL DISEASES

Epidemic cerebro-spinal meningitis is caused by a germ that grows in the membranes and fluid around the brain and spinal cord. The germ is found in the nasal secretions of those suffering from the disease. It is thought that spinal meningitis is contracted by inhaling the germ into the nose, whence it finds its way to the brain. The disease is infectious and care should be used to prevent its spread. The pneumonia germ, the typhoid germ, the germ of tuberculosis, and the pus-forming and other germs may also grow around the brain and cord and cause meningitis, but the common infectious form of the disease is caused by the germ shown in Figure 149.

FIG. 149. The germ of cerebro-spinal meningitis.

One form of *sore eyes* is caused by a bacterium. The germs are carried by flies and may be wiped on books, doorknobs, or anything which a sufferer from the disease touches. Children with this disease should not be allowed to attend school, for it is highly infectious. It is never quite safe to wash the eyes in a public basin, or to wipe them on a towel that the public has used.

FIG. 150. The bacillus that causes infectious sore eyes.

Yellow fever, *chicken pox*, *mumps*, *measles*, and *German measles* are certainly germ diseases, but the germs that cause them have not been discovered.[1] Many tropical diseases are due to either bacteria or protozoa.

[1] The incubation periods of some of the more common infectious diseases are as follows: chicken pox, usually 13 to 14 days, but may be 18 or 19 days; mumps, 13 to 21 days, though it may be shorter; measles, about 10 days; German measles, from 2 to 3 weeks; scarlet fever, 2 to 5 days; whooping cough, 1 to 2 weeks.

Bacteria affecting Animals. Among bacterial diseases of animals are chicken cholera, pink eye, distemper and glanders, in horses, blackleg in cattle, an intestinal disease of parrots, and many other animal diseases that we cannot mention here. The germs of the parrot disease, when inhaled by man, produce a very severe form of pneumonia, and the glanders germ attacks man and is often fatal to him.

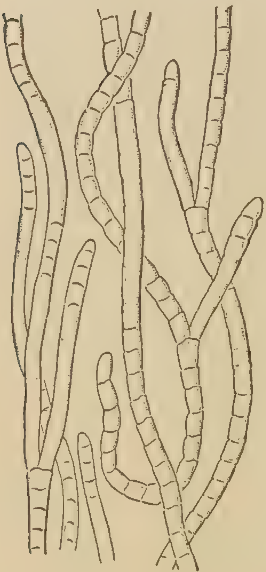


FIG. 151. The fungus that causes ringworm.

Diseases caused by Other Organisms. Many diseases of plants (rusts, smuts, mildews, rots, etc.) are caused by fungi that are related to the *molds* and *mildews*. These are much larger than bacteria, their bodies being composed of long, thread-like filaments. A few of these fungi attack man, a number of them entering the hair follicles and growing in the skin. Among the diseases caused by them are ringworm, barber's itch, and in tropical countries, an itch which attacks any part of the body. Thrush, which is found in the mouths of young babies, is also due to a fungus, and a few kinds of yeasts occasionally attack the human body.

QUESTIONS

Give some facts that show the extreme smallness of bacteria. Where are bacteria found? What shapes have they?

Where does the bacillus of diphtheria grow? How long can the germ remain alive outside the body? What is the incubation period

of diphtheria? How is it contracted? How strict a quarantine is necessary to control diphtheria? How does diphtheria cause death? What is antitoxin? Explain the antitoxin treatment for diphtheria. Why should the antitoxin be used in the early stages of the disease?

In what parts of the body does the pneumonia germ grow? How is the germ transferred from one person to another? Give some ways by which the disease may be in a measure prevented. Why is influenza a dreaded disease? How may most of the dangers of an influenza attack be avoided? Mention some of the important factors in the treatment of chronic colds. Why should young children have especial protection from whooping cough?

Name some of the diseases caused by pus-forming germs. Of what is pus composed? How should a wound made by anything clean be treated? a wound made by anything unclean?

Where is the tetanus bacillus found? Under what conditions can it grow and under what conditions can it not grow? What kind of wounds are especially dangerous? How does the tetanus germ injure the body? What germ does the leprosy bacillus resemble? How is plague spread?

How does the typhoid germ enter the body? What excretions from a typhoid patient contain the germs? What discovery has helped greatly in controlling this disease? Name some of the ways in which typhoid fever may be contracted. How does the cholera germ enter the body?

By what germs may cerebro-spinal meningitis be caused? Where do the germs grow in this disease? In what secretion of the patient is the germ found? How does the germ probably enter the body?

How may the germ that causes sore eyes be spread? Name other germ diseases; some germ diseases of animals; some diseases caused by larger fungi.

When one has been infected with diphtheria or tetanus germs, antitoxin helps to keep the disease from developing. How does it do this? Are typhoid germs killed by freezing them in ice?

CHAPTER XXV

PREVENTING THE SPREAD OF DISEASE GERMS

After most kinds of disease germs begin their growth in the body, medicines are of very little use except to keep up the body strength. In our warfare with germs, we must therefore depend chiefly either on keeping the germs out of the body, or on the natural power of the body to kill them after they enter it. Keeping up the germicidal power of the body, and preventing the germs of infectious diseases from being scattered about, are, therefore, the most important points in the prevention of disease. In a former chapter (page 290) we have discussed the necessity of keeping up the resistance of the body to germs. We shall now study the best methods of keeping the germs that come from the bodies of sick persons from being spread abroad.

DANGERS FROM INSECTS

Fleas spread the germs of plague; mosquitoes carry many diseases; the house-fly is a great carrier of germs; and ticks and certain tropical flies are known to carry disease. The bedbug also is suspected of being responsible for the spread of certain diseases. Any insect that bites us has an excellent opportunity to introduce germs into the body, and any insect that crawls over our food, as do flies and cockroaches, may easily spread the germs of many diseases. We shall do well, therefore, to guard ourselves as much as possible from insects.

Mosquitoes. The mosquito, more than any other one agency, has driven man from the warmer and more fertile portions of the earth to the colder and more barren regions. Not only does it carry the germs of malaria, but it carries yellow fever and dengue, or "breakbone fever," a disease common in the tropics and found to a certain extent in some of our Southern states. The germs of several diseases of man not found in our country, and of certain diseases of birds,

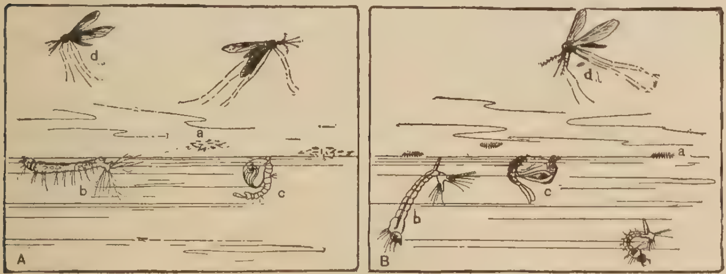


FIG. 152. The life history of the mosquito. *A* is the malaria-carrying mosquito (Anopheles), and *B*, the common mosquito (Culex). *a* is the eggs; *b*, the wiggler; *c*, the tumbler; and *d*, the adult mosquito.

are also carried by mosquitoes. Where it is possible to do so, the best way to end these diseases is to destroy the mosquitoes. To work at this intelligently it is necessary first to know the life history of the mosquito.

The Life History of the Mosquito. The mosquito lays its eggs on water. In about a day the egg hatches into a *wiggler* that swims actively about, feeding on protozoa and other small animals that are in the water. The wiggler takes in air through a breathing tube, which it thrusts out through the surface of the water to the air, as shown in Figure 152.

In from seven to fourteen days the wiggler changes its

form. The head and the fore part of the body become much heavier, and the breathing tubes shift to the back of the body. In this stage it is called a *tumbler*, because instead of wiggling as it swims, it tumbles over and over. In from two to five days — ten to twenty days from the time the egg was laid — the tumbler splits down the back, and the adult mosquito comes out and flies away. How long a mosquito lives in the adult form is not known, but one has been kept

FIG. 153. *A* is the malaria mosquito (Anopheles) and *B* is the common mosquito (Culex).

for seventy-six days, and enough of them always live through the winter to furnish a plentiful supply for the next summer.

Anopheles. The kind of mosquito that carries the germ of malaria is called *Anopheles*. It is a small, almost silent mosquito, that does most of its biting in the early part of the night. It can readily be distinguished from other mosquitoes by the black spots on its wings, and by its habit of elevating the back part of the body, or standing up on its head, when sitting and biting. The wiggler of Anopheles can be distinguished from the wiggler of other mosquitoes by its position while breathing. The Anopheles wiggler lies almost parallel to the surface of the water (Fig. 152 *A*), and the other wigglers take a position almost perpendicular to the surface of the water (Fig. 152 *B*).

Other mosquitoes are often carried considerable distances by the wind, but the Anopheles has a habit of clinging to weeds, shrubs, and bushes when the wind blows, and is not often found far from the place where it is hatched. The mosquitoes that give people malaria are usually raised by those same people, or by their near neighbors.

How to destroy Mosquitoes. The first thing in the fight with mosquitoes is to deprive them of breeding places near human dwellings. An old fruit can may catch and hold enough rain water to breed a large number of mosquitoes; in the course of a summer, an almost unlimited number can come from a water barrel or an open cistern; and an undrained ditch by the roadside may supply enough mosquitoes to torment and infect with malaria all the people in the vicinity.

Old cans and pans should be cleared away; water barrels, tanks, and cisterns should be screened so that the mosquitoes cannot get to them to lay their eggs; sagging eave troughs should be braced up so that no water will stand in them, for wigglers may start here in a very small quantity of water and be washed down into the cistern, where they will complete their development. All pools and puddles about houses should be drained, and weeds and shrubbery in which the mosquitoes can find a dark, cool place to hide during the hot part of the day, or when the wind blows, should be cut down.

When pools of water cannot be drained, it is an easy matter to kill all young mosquitoes in them by pouring a little kerosene on the water. This forms a film over the water, shutting the wigglers off from the air, and killing them in a few minutes. If the kerosene is washed away by rains, it must be renewed within ten days, for this is about the time it takes a mosquito egg to grow into a mosquito. Minnows

feed on the mosquito wigglers, so by introducing these into a pond, the number of mosquitoes that breed there may be greatly lessened.

The work of destroying mosquitoes in cities and towns must be taken up by public officials who have authority to compel every one to put his premises in sanitary condition. Otherwise enough persons will keep breeding places for mosquitoes to infect the whole town. When the work is undertaken in this way, it is a simple and not at all expensive matter entirely to eradicate mosquitoes and malaria from a town, as has been done in many places.

The Danger of Flies. There is a belief among some people that flies are useful scavengers. No greater mistake could be made, for they light in and walk over all manner of unclean matter, and then fly into the house and spread germs and uncleanness over dishes, food, milk vessels, and everything that they come in contact with.[1] Not only do they carry germs on their feet, but when a fly feeds on the sputum of a consumptive or the wastes from a typhoid patient, the germs of these diseases are found alive in the matter from its alimentary canal.

FIG. 154. The foot of a fly. A fly usually has great numbers of germs clinging to its feet.

Flies may carry almost any kind of disease germs, so a sick person should be carefully screened away from them, and all matter from the body of a sick person should be destroyed immediately. Otherwise, every one in the vicinity is in danger of contracting the disease through the flies.

[1] A fly was caught and made to walk over a plate of gelatine for two minutes. In that time it left 289 germs in the gelatine. Another fly has been reported as having 100,000 germs on its legs.

Keeping Free from Flies. It is possible to do much in the way of avoiding danger from flies by using screens and flypaper, by covering food and dishes, and by removing all materials that attract them to the house. A far easier and more effective way is to remove the breeding places of the flies. The egg of the house-fly is laid in manure about stables, in garbage, or in dry closets. In a day or less, this hatches into a small, white, footless maggot, which in nine or ten days from the time the egg was laid changes into the adult fly.

FIG. 155. The house-fly. *A* is the egg which is laid in manure; *B* is the larva or maggot; *C* is the pupa or resting state; and *D* is the adult fly.

It is estimated that as many as 300 flies may hatch in a cubic inch of manure, and if the breeding places of the flies are left undisturbed, they will hatch faster than it is possible to kill them. It is a simple matter, however, to stop their increase by removing, once a week, all matter in which they breed, burying it, or spreading it on the fields where it will dry and the eggs and young will be killed.

Flies can also be prevented from hatching by covering the matter in which they breed with lime. Full directions for preventing the hatching of flies in manure by the use of borax or hellebore may be obtained from the United States Department of Agriculture.

DANGER FROM DUST

In a cubic yard of ordinary air, there are from a hundred to a thousand bacteria. These bacteria are attached to floating particles of matter of one kind or another. Air that

is absolutely free from dust is also free from bacteria, and by stirring up dust the number of bacteria in the air can be increased to countless multitudes.

It was formerly believed that disease germs were blown about in dust, and that the germs of respiratory diseases were frequently carried into the air passages in dust. It is possible that indoor dust, which contains pulverized sputum, may at times have in it living disease germs, but as a carrier of germs dust is of little importance; for the germs of all our ordinary diseases are killed by light and thorough drying, and in outdoor dust their lives quickly come to an end.

Nevertheless, it remains true that dust is highly dangerous; for it wounds the walls of the air passages and allows any germs that may be in these parts to set up their growth. Every possible effort should, therefore, be put forth to prevent dust. Streets should be cleansed and sprinkled, houses should be swept with carpet sweepers or damp brooms, and some damp material[1] should be used in sweeping public schoolrooms and other public buildings. Schoolrooms should be swept after school so that there will be time for the dust to settle before the pupils assemble the next morning, and other public buildings should be

[1] The Michigan State Board of Health recommends the following for use in sweeping the floors of public buildings:

(1) To a pailful of sawdust wet with hot or cold water, add one half pint of kerosene and a tablespoonful of sulpho-naphthol or formaldehyde. This material can be prepared some days in advance of its use.

(2) Heat one third part sand, and add two thirds part sawdust. To a pailful of this mixture add one half pint of paraffin oil and mix thoroughly. This preparation produces excellent results.

(3) Boil one pound of salsoda and one pound of chlorid of lime in a gallon of water. Dampen sawdust to be used for sweeping with this solution. This preparation is excellent for restoring the natural color of floors.

swept some time before they are to be used. Dusting should be done with a damp cloth that will wipe off the dust and take it away, for it is foolish simply to stir up the dust into the air, where it will be inhaled or will settle again on objects in the room. In rooms that are much used, hard floors, rugs, and plain furniture are more hygienic than heavy carpets and plush-covered furniture, because it is easier to keep them free from dust. Vacuum cleaners are recommended by health officials, because they remove dust and do not stir it up where it will be breathed into the lungs.

DANGERS FROM WATER AND FOOD

Typhoid, dysentery, and diarrhea are the main diseases that are carried by water. All over our country, every year, many persons contract these diseases from the water, and occasionally the water supply of a city will be so infected that an epidemic will occur. The way water may be polluted is shown by the history of the typhoid epidemic from which Butler, Pennsylvania, suffered in the summer and autumn of 1903.

Butler was then a city of about 16,000 inhabitants, supplied with water from an artificial lake. A family living on the banks of a small stream that flowed into the lake was stricken with typhoid, and the wastes from the sufferers were thrown out on the ground near the creek. The germs found their way into the creek, and into the water that was used in the city, and soon great numbers of the inhabitants were stricken with typhoid, about 1200 cases developing before the epidemic was over. One section of the city was supplied with water from artesian wells, and the people using this water did not suffer from the disease, which shows that the germs were carried by the polluted water from the lake.

Epidemics like the one in Butler are, of course, uncommon, but if you will investigate, you will probably find that in the town or community in which you live, several persons die each year from these water-borne diseases.

Freeing Water from Disease Germs. By filtering through beds of sand, a city can take almost all dangerous germs out of its water supply. Many cities fail to do this, however, and when one must use impure city water or water from an ordinary well, the best plan is to boil it. Bringing it to a boil will kill all dangerous germs, most of them dying if the water is heated to 160 or 170 degrees. Most house filters are almost useless, for they catch matter in which the bacteria breed and multiply, and the bacteria pass through the pores in most of them. Filters made of fine porcelain do keep back bacteria if they are carefully cleaned and attended to, but this is a great deal of work, and it is easier to boil water than to look after a filter. It is always to be remembered that to wash fruits, vegetables, dishes, or milk vessels in impure water may be as dangerous as to drink the water.

Disease Germs in Natural Waters. Any water that comes from the surface of the ground is likely to contain disease germs, typhoid fever being a very common disease in the country and in mountainous regions, where the people drink from the most beautiful, clear springs. Shallow wells, springs, and small streams are the most dangerous of all waters. Cistern water, where the cistern is closely cemented and kept clean, is much safer. Water caught from a roof and stored in a tank above ground is safe, and deep artesian water is also free from dangerous germs. It is never safe to use water from a shallow well, no matter how cool and clear the water may be, for experience shows that people who use such water suffer greatly from typhoid fever and

other intestinal diseases. Some wells are much worse than others, an occasional well giving typhoid to almost every family that uses water from it. Such a well should be filled up, and if water from a suspicious source must be used for drinking, it should be boiled.

Keeping Bacteria out of Wells. Very few bacteria live deeper than five or six feet[1] in the soil. The pollution

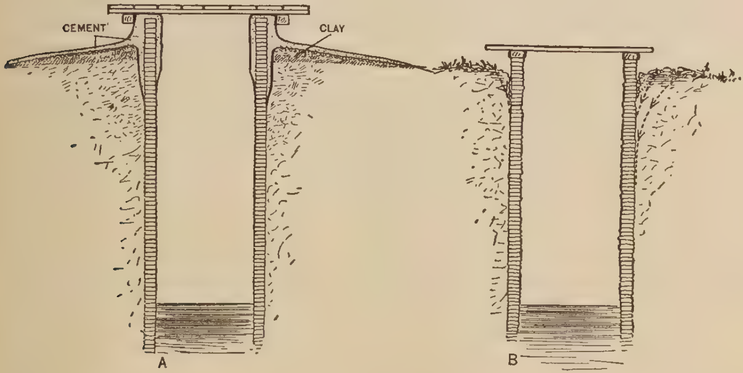


FIG. 156. *B* shows how surface water enters a well, carrying with it germs from the surface of the soil. *A* is a well arranged to keep out surface water and germs. The water must not be allowed to run down behind the wall, the platform should be double and water tight, and water should not be allowed to run back into the well around the pump.

of wells comes from surface water getting into them when it rains, and carrying with it bacteria from the upper layers of the soil.

To keep out bacteria, a well should first of all be located on a high place and away from all pigpens, stables, or outbuildings that may drain into it. Around the mouth of the

[1] Where the soil is very coarse gravel or where it is underlaid by sloping, cracked layers of rock, germs may travel considerable distances underground.

well a tough clay should be spread and packed in thoroughly, so as to form a water-tight layer over the soil. This should slope so as to carry all surface water away from the well. A sound, clean, water-tight platform, large enough to extend out over the walls, should be built, so that no surface water whatever will run in behind the wall and get into the well.

The whole task is to keep the surface water out of the well. Cementing the upper part of the well and laying a circle of cement over the surface of the earth above the mouth of the well is the surest way of doing this. Where there are disease germs in the ground, some of them are likely to get into the water, but their number can be greatly lessened by taking proper care of a well. Also a great deal of the food materials on which the germs in the water grow and multiply is kept out of the well by these precautions. No one who is nursing a case of infectious disease should come about the well, or if he does so, at least should use great care, for it is an easy matter, by handling well-buckets or by working around a pump, to leave germs where they will get into the well.

Dangers from Milk. The great danger from milk is due to the fact that most kinds of germs multiply rapidly in it. Tuberculosis is sometimes caused by milk, and the sickness that is so common among young children in summer is often due to germs in the milk. Typhoid fever, scarlet fever, and diphtheria may also be contracted through milk. Again and again it has been found that along the route of a certain milkman the people were suffering from one of these diseases, and on investigation it would be proved that a case of the disease existed among those handling the milk or in their families; or that the bottles had been taken back from families where the disease was, or, in epidemics of typhoid

fever, that the milk vessels had been washed in water from wells containing the typhoid germ. One article in a medical journal reported 330 epidemics traceable to milk, of which 195 were typhoid epidemics, 99 were epidemics of scarlet fever, and 36 were diphtheria epidemics. It is difficult for a private citizen to guard himself against these dangers, and in all well-governed cities and towns a health officer looks after the milk supply.

Keeping Milk Free from Germs. All milk vessels and feeding bottles for babies should be thoroughly scalded every day to kill the germs in the milk that adheres to them. Otherwise these germs will multiply in the new milk, and soon it will be filled with them (page 303). Milk vessels should never be rinsed in any but boiled water, the purest of rain water, or artesian water, for one dangerous germ that gets into the milk from the water remaining on the vessels may grow into a multitude. Milking should be done in a clean building that has fly screens on it, and everything possible should be done to keep dust and hairs out of the milk, for these are swarming with germs. The milk should be cooled as quickly as possible, and kept cool to prevent the germs from multiplying so rapidly (page 130). It should be used before it becomes old, for milk that at first has only a moderate number of germs in it may soon be filled with countless myriads of them. It is also necessary for a medical officer to examine the cows from which the milk comes, or there will frequently be living tuberculosis germs in the milk (page 341).

Killing Germs in Milk. When it is impossible to obtain clean fresh milk, it is often advisable to heat milk to 170 degrees or a little higher for a few minutes, or to heat it to 155 degrees for half an hour. This destroys most of the

germs in the milk, and a person using the milk has fewer of them to kill out. A few children, however, do not digest the heated milk so well as raw milk, and heating does not render wholesome very old milk, in which the germs already have produced large quantities of toxins and acids. In the summer, however, ordinary milk is in most cases greatly improved by heating.

Dangers from Other Foods. Almost any food may be a carrier of disease if it has been exposed to flies or placed where the public may handle it. The intelligent citizen buys his food from the groceryman who keeps a clean store and screens his fruit and vegetables from flies.

DISINFECTION

It cannot be too strongly emphasized that nearly all our germ diseases come from other persons who are diseased, and that insects, water, and milk are sources of danger because they may become contaminated with germs from the body of some person. In preventing the spread of germ diseases, the destruction of the germs in sputum and in the other discharges from the bodies of the sick is therefore more important than any other precaution. It is well for every one to know some of the ways of killing germs.

Drying. Disease germs, like other plants and animals, are killed by too great loss of water. Even the tuberculosis germ is killed by sufficient drying, and in disinfecting a house the important thing is not to fumigate the walls with a gas but to scrub the floor with a strong disinfectant, thus reaching the germs in the crevices and removing mucus or other matter that may protect them. A damp house tends to keep alive the

germs that are in it, and consumption, pneumonia, and other diseases are more likely to develop in a damp house than in a dry house.

Light. Light is injurious to bacteria, bright sunlight killing many germs in a few minutes, and a moderately strong light assisting in checking their growth. It is an excellent practice to expose bedclothes and rugs to the sun, and to throw up the shades and allow the light to enter houses. In rooms occupied by consumptives, or by pneumonia, diphtheria, or grip patients, this is especially valuable. Besides the effect which light itself has on the bacteria, admitting the light dries out a room, and assists in this way in killing the germs. Dirt and dust, mingled with sweat and oil from the skin, on doorknobs, banisters, and furniture, protect germs from light and drying, thus keeping them alive. For this reason the doorknobs and desks in schoolrooms should be cleaned occasionally with soap and hot water.

Heat. Boiling water kills the germs of all common diseases, and handkerchiefs, dishes, and clothing that have become infected can be made safe again by thoroughly boiling them. Articles of little value, and sputum from patients sick of respiratory diseases, may often be most conveniently disposed of by burning (page 342). The surfaces of dishes contain tiny crevices in which germs lodge, and in disinfecting dishes with hot water, it is necessary to leave them for a few minutes in boiling water, so that the heat will reach the germs in the crevices.

Chemical Disinfection. Certain chemicals are so poisonous to germs that they are extensively used in disinfecting. A physician should always be consulted as to which disinfectant is best for a particular purpose, and exactly how to use it, for some of them are better for one purpose than

for another. Since most of these disinfectants are very poisonous, an excellent plan is to add a little red ink or other coloring matter to them so that they will not be mistaken for water. The following are some of the most commonly used disinfectants:

Bichlorid of mercury (corrosive sublimate) dissolved in water, with one part of the bichlorid to a thousand parts of water (1 dram to 1 gallon of water), kills nearly all kinds of germs in two or three minutes, and all kinds in fifteen minutes. This can be purchased in tablets of the right size to make a pint or half pint of the disinfectant of the proper strength. It is convenient, and an excellent disinfectant for the hands, for washing floors and furniture, and for disinfecting clothing that can be soaked in it. It cannot be used on metal, as it destroys it, and is not good for disinfecting where there is much organic matter present, as there is in discharges from persons sick with typhoid and other intestinal diseases.

Biniodid of mercury is more than twice as powerful as bichlorid of mercury, and need be made only half as strong. It is one of the best general disinfectants, and is especially useful in disinfecting the hands, since it does not injure the skin as do most other disinfectants.

Carbolic acid, made up in a $2\frac{1}{2}$ per cent solution ($3\frac{1}{2}$ ounces of liquid carbolic acid to 1 gallon of water), is as strong as the bichlorid of mercury solution described above. This is a very reliable disinfectant, good for almost any purpose. For disinfecting sputum and other discharges from the body it is well to use a 5 per cent solution.

Lysol is about the same strength as carbolic acid. It often destroys the colors in clothing.

Formalin is about one half as strong as carbolic acid, a 5

per cent solution being equal to a 1 to 1000 solution of bichlorid of mercury. It loses its strength if exposed to the air. By heating formalin, a gas called *formaldehyde* is driven off. This is the best of all gaseous disinfectants.

Chlorid of lime, made by adding $1\frac{1}{2}$ ounces of chlorid of lime to 1 gallon of water, is a cheap and powerful disinfectant.

Milk of lime is a powerful disinfectant. It is made by adding one part of freshly slaked lime by weight to four parts of water. This is a cheap disinfectant, and, for certain purposes, is as effective as anything that can be employed. It should not be used in sinks, for it will cause trouble with the traps. Air-slaked lime is worthless.

Special Points in disinfecting. Any one who is waiting on a person sick with an infectious disease should frequently and thoroughly disinfect his hands, holding them for several minutes in the disinfectant. Washing the hands thoroughly with soap assists very greatly in freeing them from germs. Keeping the nails trimmed and the skin smooth makes the hands easier to disinfect.

For treating an infected wound or a sore, peroxid of hydrogen and iodin are often used. A weak solution of carbolic acid or a carbolic salve is also good, and washing with warm salt water is useful (page 312). In vaccination the skin should be cleansed, clean instruments used, and the wound protected; for the greatly swollen arms and running sores that sometimes follow vaccination are caused by pus-forming germs that get into the wound.

In typhoid fever, the germs are in the discharges from the bowels and the kidneys, and should be received in vessels containing disinfectants. Strong limewater is excellent for this, and carbolic acid is also good. It is necessary to see that the disinfectant is thoroughly mixed with the waste

matter, and it should be allowed to stand for several hours to make sure that all germs are killed.

In diphtheria, pneumonia, consumption, grip, measles, scarlet fever, and spinal meningitis, the germs are in the discharges from the throat and nose. It is best to receive these discharges in strong disinfectants, carbolic acid being good for this purpose. Above all, do not allow the discharges to infect articles in the room. All handkerchiefs, dishes, and other infected articles should be placed at once in boiling water or soaked in carbolic acid or bichlorid of mercury. These substances are poisonous, and must afterwards be rinsed off dishes. Additional instructions in regard to the disinfection of sputum will be found in the chapter on consumption (page 342).

Where a whole room or house is to be disinfected, it is usually done by fumigating. Formaldehyde, or sometimes sulphur, is used for this purpose. Special directions are necessary for this work if it is to be effectively done. Quicklime is a good disinfectant for cellars and closets, and the germs in any matter that is buried in quicklime will be killed.

Mistaken Ideas in Regard to Disinfection. The idea that there is some connection between the smell of a substance and its power as a germ killer is prevalent. Odoriferous substances are sometimes burned in rooms containing sick persons, or a little carbolic acid exposed in a saucer so that it will scent the air of the room. It need hardly be pointed out that germs are not injured by anything of this kind.

Unhygienic Habits. There are numerous ways by which germs can get into the body, and we will call attention to a few habits which give them a special opportunity to do so. One of these is the habit of putting pencils and other

objects into the mouth, often after these same objects have been in the mouths of other people. Another is the habit of drinking from the same cup that others use. Germs may easily be left on a cup by any one who has them in his mouth, and each child in school should have his own cup, and in traveling one should carry a private cup. When it is necessary to drink from a public cup, it is better to put both lips into the cup and drink without taking the edge of the cup into the mouth. One other habit that we would mention is that of allowing the fingers to touch the face, eyes, or lips. In many ways — from books, doorknobs, pencils, seats and straps in street cars, and from the hands of other persons — we get germs on our hands. It is, therefore, advisable to form the habit of keeping the hands away from the face. Especial attention should be given to this point when sore eyes are prevalent. A good habit to form is that of washing the hands with soap before eating (page 335).

Freeing the Country Farmhouse from Disease. By intelligent effort, families living in the country can greatly decrease the risk of exposure to germs. If they will clear away weeds and dense shrubbery from around their homes and look after the breeding places of mosquitoes, they can do much to protect themselves against malaria. By removing the breeding places of flies and guarding their own milk and water supplies, they can in a great measure free themselves from typhoid fever. Sunlight admitted to the house is a great aid in keeping the atmosphere free from germs, and the fresh country air admitted freely to the sleeping rooms at night will do much to build up the body and increase its germicidal power. Germ diseases are almost as prevalent in the country as in the city, but with a little care a family in the country can, to a great extent, avoid them.

City and Village Improvement. If the inhabitants of cities and towns will work together, they can do much that will give them more healthful and also more pleasant and beautiful places to live. Sprinkling the streets and sodding with grass along the sidewalks will help to keep down the dust. Clean sidewalks are pleasanter than sidewalks that are covered with sputum, and a street car that has been soiled by persons spitting on the floor is neither inviting nor sanitary. By cutting down the weeds and looking after the breeding places of mosquitoes, the town is made more beautiful and attractive as well as freed from malaria, and killing out the flies saves us from annoyance as well as from disease. The intelligent citizen favors the improvement of his town because it gives him a more pleasant place to live, and because he knows that it costs far less to make a town clean and healthful than to have all the disease that comes from insects, unclean streets and sidewalks, dust, bad water, and impure milk.

The Necessity for Public Health Officials. There are always some careless persons who will spread disease if they are permitted to do so, and in a town or city, it is impossible for a person to protect himself against germ diseases by his private efforts. He has no control of his neighbor's flies and mosquitoes, and he cannot prevent consumptives from scattering germs about where he is likely to inhale them. If he lives in a city, he has no water except that which comes to him through the city water mains, and no milk supply except that which the milkman furnishes him. His children may go to school and there be kept in an unclean, badly ventilated schoolroom, and seated beside some one who has just recovered from diphtheria, and who is still carrying virulent diphtheria germs in his throat. With-

out public health officers, a private citizen will be exposed in a hundred ways to danger from disease germs. It is, therefore, the duty of every good citizen to uphold the health officials and to work with them, and every one should realize that it is a great moral crime to scatter abroad germs that may cause sickness and death.

Summary. Disease germs are carried by insects, dust, water, and food, and in other ways. They come from persons who have germ diseases. By destroying the germs that come from these persons, more can be done to prevent sickness than in any other way. Country people may protect themselves against germs, but in cities and towns health officials are necessary.

QUESTIONS

What insects carry disease germs? What diseases are carried by mosquitoes? Give the life history of the mosquito. How may the malaria-carrying mosquito be distinguished from other mosquitoes? How may mosquitoes be destroyed? How do flies carry germs? How may flies be destroyed? Mention some measures that assist in the prevention of dust.

Name some diseases that are carried by water. Tell of the Butler typhoid epidemic. How may water be kept safe from germs? What natural waters contain disease germs? What kinds are safe? Tell how to protect a well from germs. What diseases are carried by milk? What measures are necessary to keep milk safe from germs? How may disease germs in milk be killed? What precautions should be taken to keep germs from foods?

Name four ways in which germs may be killed. Name some common chemical disinfectants. How should sputum be disposed of? Mention some unhygienic habits. What measures will assist in freeing a farmhouse from disease? in freeing cities and towns from disease? Why are health officials necessary?

CHAPTER XXVI

TUBERCULOSIS

About one seventh of the human race and one tenth of the inhabitants of the United States die of tuberculosis. Each year this disease claims in Europe about one million victims, and in our own country about one hundred and fifty thousand. This means that each day four hundred of our countrymen die of tuberculosis, and that eight millions of the people now living in the United States will die of the disease. It is estimated that tuberculosis costs our nation in money $1,000,000,000 a year, an annual sum that, if properly expended, would free the land from the disease.

The Bacillus of Tuberculosis. Tuberculosis is caused by a slender bacillus that attacks most vertebrate animals as well as man. It may grow in almost any part of the body and cause tuberculosis of the part affected. When it grows in the intestine, it causes tuberculosis of the intestine. When it grows in the bone, it causes tuberculosis of the bone. When it grows in the lymphatic glands, it causes the disease formerly known as scrofula, and when it grows in the lungs, it causes tuberculosis of the lungs, or consumption. The germ of tuberculosis may also grow in the skin, kidneys, liver, or larynx, but it most frequently attacks the lungs.

Fig. 157. The bacillus of tuberculosis.

The bacillus of tuberculosis is slow-growing, but it is so hardy that it often resists all efforts of the body to kill it, and grows steadily on and on until it causes death. Outside of the bodies of men and animals, it does not grow at all in nature, and under the influence of light and drying, it finally dies. Yet in the sputum of a consumptive, it often lives for two or three months — sometimes even for a whole year. Pulverized sputum in indoor dust may therefore be a source of danger to all who breathe it in. Away from the habitations of men and animals, the tuberculosis germ is not found, but it is frequently present in rooms that have been occupied by careless consumptives.

HOW TUBERCULOSIS IS CONTRACTED

Tuberculosis is contracted from men and animals that have the disease. The germ gets into the body usually either from the milk of diseased cattle or, more commonly, from the sputum of a consumptive.

Tuberculosis Germs in Milk. A great number of cattle are affected with tuberculosis. Occasionally the germs are in meat, but more frequently they are in milk.[1] It is known that the germs of tuberculosis can pass through the wall of the alimentary canal, be carried by the blood to the lungs, and there start consumption. Since no one wants to drink living tuberculosis germs in his milk, dairy cattle should certainly be properly inspected to see that they are free from this disease. Yet the Alaska Indians, the Filipinos, and many other peoples who do not use milk suffer greatly from

[1] From examinations of milk made in Washington, D.C., it was estimated that almost 7 per cent of the milk sold in the city contained living tuberculosis germs. The germs are also found in butter that is made from infected milk, and will remain alive and virulent in butter for weeks and months.

tuberculosis, and it is probable that most tuberculosis comes not from milk, but from persons who have consumption.

Dangers from Sputum. In the advanced stages of consumption, the sputum that is brought up from the lungs each day contains several billion germs. This sputum should never be swallowed, for if this is done, there is danger that the disease will be started in the walls of the alimentary canal, or that the germs will get into the blood and be carried to parts of the body that have not yet been infected. It is also unsafe to spit the sputum out where it will be exposed to flies, or to let it dry and blow about, for it may cause other people to contract the disease. The germs in the sputum should therefore be destroyed.

Disposal of Sputum. The sputum from a consumptive should be received in a vessel that contains a disinfectant (carbolic acid or chlorid of lime is good for this purpose), or in pasteboard cups that may be burned. Sometimes the sputum is received in vessels that contain water, and is then disinfected with boiling water or buried in lime, but it is safer to receive it in a disinfectant. When the consumptive is away from home, he may use pieces of cloth and seal them up in waterproof envelopes that are made for the purpose, until they can be destroyed.

Other Precautions to be taken. A consumptive should always hold a handkerchief before his face when he coughs, and these handkerchiefs should be placed in disinfectants, or should be thoroughly boiled. He should learn to keep his hands away from his face and mouth, and should occasionally wash his hands in a disinfectant. He should have his own dishes, and these should never be washed with those of the family, nor allowed to come in contact with them until they have been boiled for at least five minutes. His bedclothes,

clothing, and furniture ought occasionally to be disinfected, or at least exposed to the bright sunshine as much as possible, and his clothing should be boiled before it is washed with other clothes. A consumptive should have a sleeping room to himself, and this room should be kept bright and well ventilated, to help kill any germs that may be free in it. A house in which a consumptive has lived should be disinfected before any one else moves into it.

Danger from a Consumptive. Recent studies indicate that there is little danger from a brief contact with a consumptive, but that the long-continued and heavy infection that comes from living with a careless consumptive is highly dangerous. A consumptive should, therefore, live apart from other members of the family, and in every way he should strive to save others from infection with the germs. If possible, he should go to a sanatorium where he can have proper treatment for his disease.

THE TREATMENT OF CONSUMPTION

Probably every one takes in tuberculosis germs at some time, and in the lungs of most persons there are scars showing where the tubercle bacilli have started to grow, but have been destroyed. It is, therefore, a great mistake to think that consumption is incurable.

Importance of Early Treatment. Any one who has symptoms of consumption[1] should not try to persuade himself that his symptoms have no existence, for this will not stop the growth of the germs. He should not lose valuable time experimenting with patent medicines, for there is no medi-

[1] The most common symptoms of consumption are cough, loss of appetite, gradual loss of flesh and strength, fever, night-sweats, and blood-spitting. The cough is often absent in the early stages of the disease. Only an examination by a reliable physician should satisfy one.

cine known that will cure consumption. The only sensible thing for him to do is to be examined at once by a physician who thoroughly understands the disease. Then, if he finds that the germs have gained a foothold in his lungs, he should give himself the best possible treatment at once, for everything depends on starting the treatment early.

Important Factors in Treatment. In the successful treatment of consumption, the following are the more important factors:

Rest. If a consumptive can be kept quiet, much of the toxin that is produced by the germs will be thrown off in the sputum. Anything that causes the breathing to be quickened and deepened causes more of the toxin to be carried from the lungs through the body, and increases the fever

A consumptive should therefore have rest. If he has fever, he should have absolute rest, not even walking about his room. Laughing and loud talking should be avoided, and coughing should be refrained from as much as possible. When there is no fever, a little exercise may be taken, but it should be taken with care.

Food. A consumptive should have an abundance of food, especially of protein and fatty foods. Meats, eggs, milk, and any other good foods that he can eat and digest should be taken. Lunches should be eaten between meals and on retiring. The foods must be well prepared and served in different ways, or the patient will become tired of them.

Outdoor Life. Nothing in the treatment of consumption is more important than fresh air, and the disease has been most successfully treated where the patients have lived and slept in the open air, summer and winter. Usually an upper porch can be arranged with little expense, so that the patient can sleep on it. In outdoor sleeping in winter, it is necessary to have warm clothing and to wear some kind of hood to protect

the head and neck, and in many places in summer it is necessary that the patient be screened from mosquitoes.

Other Important Points. Warm and dry clothing is of course important, and if a consumptive lives indoors, he should, above all else, be sure to have plenty of fresh air. Consumption is much more frequent in damp houses and on wet soils, than it is in dry houses and on sandy soils. A consumptive should not remain in a damp house, and if he lives outdoors, he should locate himself on a dry soil. He should not worry about his disease being inherited, but should be cheerful and hopeful, for if he takes his disease in time, he has every reason to hope for recovery. The great importance of early treatment must be understood, however, and early symptoms like languor and loss of weight must be recognized; for after the cough has become established and the germs appear in the sputum, a portion of the lungs has already been destroyed.

Sanatoria for Consumptives. Many states have established sanatoria to which consumptives can go, and, at a slight expense, remain until they recover from the disease.[1] This is sensible, for in a sanatorium a consumptive can have proper food and care at much less expense than he can have them at home, and the physicians in the sanatorium know how to disinfect so that there is no danger of the spread of the disease. It is much more economical for the people of a state to care for their consumptives in sanatoria than out of them, and it is much pleasanter both for the consumptives and for those who have not the disease.

[1] Many state and city boards of health publish circulars giving very full and detailed information in regard to the treatment of consumption. A consumptive should write to the health board of his state for these circulars, for they will enable him to care for himself much more intelligently.

The Effect of Climate on Consumption. It was formerly supposed that climate was very important in the treatment of consumption, but consumptives are now being cured in all our states, and it has been found in treating this disease, that rest, food, and fresh air are of much more importance than climate. Unless a consumptive has money enough to support himself without work and to give himself proper care, he should not leave his home for a distant state. For in many places consumptives are not welcomed, and it is better to be at home and have the proper care than to be without money or friends in the best climate in the world. A hot climate or a high elevation, however, is injurious to consumptives, for in such a place the respiration is quickened.

Summary. Tuberculosis costs us 150,000 citizens and $1,000,000,000 annually. It is sometimes contracted from milk, but usually from the sputum of consumptives. Consumption readily yields to treatment when taken in the early stages. Rest, an abundance of food, and fresh air are the most important factors in the successful treatment of the disease.

QUESTIONS

Give some facts that show the importance of tuberculosis. Tell something about the bacillus of tuberculosis. How does it get into the body? How do tuberculosis germs that are swallowed in milk get to the lungs? Why is there reason to think that sputum is a more common cause of consumption than milk? Why should sputum be destroyed? How may this be done? What other precautions should be taken in consumption? When is a consumptive to be feared? Give three important factors in the treatment of consumption. Mention some other points that are to be looked after. What advantages come from having sanatoria for consumptives? How important is climate in the treatment of consumption?

APPENDIX

A. FOODS

When the foods are oxidized in the cells, and when a piece of wood is burned in the fire, the process is the same, — the molecules are broken down, and their atoms are united with oxygen. What happens to the foods within the cells may perhaps be made clearer, therefore, by considering what happens in the burning of a piece of wood or coal in a fire.

The Burning of a Piece of Wood. Lay a piece of wood in the fire, and in a little while the wood is all gone. A few ashes may remain, but these are only a little mineral matter that was in the wood and did not burn. What has become of the wood?

The answer is that the wood has been changed to gases[1] which you cannot see, and has passed off into the air. The wood molecules, like starch and sugar molecules, are built up of atoms of carbon, hydrogen, and oxygen. In the fire these large molecules are broken to pieces, and the atoms in them unite with the oxygen of the air. The carbon, when it unites with oxygen, forms carbon dioxid. The hydrogen of the wood goes off in water vapor, which is invisible when it is hot. By holding a cold[2] glass vessel over a burning piece of wood or over a burning candle, you can catch and condense on the inside of the vessel the water that is given off. Of what elements is the fat of a candle composed? (Page 83.) Is the water in the candle, or is it formed when the fat burns?

[1] Smoke is composed of fine pieces of carbon that fly off into the air without being burned. Only a very small part of wood or coal passes off in this way.

[2] The vessel must be held over the flame only a very short time, or it will become so hot that the water will not condense on the glass. A tall vessel made of heavy glass should be used.

Energy set Free by Oxidation. Energy is stored in wood molecules, and in the fire we get heat and light from these molecules; energy is stored in the molecules of coal, and an engine gets its heat and its power to move from burning coal; in the food molecules, too, energy is stored, and by burning these molecules the cell gets its heat and its power to work. By oxidation, the energy in the molecules is set free.

The amount of energy the body needs depends on size, age, sex, and the work done.[1] In proportion to their weight young persons need more food than older ones, and women and girls require somewhat less than men and boys.

Effects of Too Little Food. A group of young men placed on a diet too low in energy value grew thinner until they had lost a little more than 10 per cent of their weight. After that their bodies continued to live at this lower level without further loss of weight. They did not become ill, but they lacked vigor, and when they attempted severe muscular exercise they lacked the strength for it.

In this undernourished condition, the tissues are poor in fat and

[1] An average-sized man needs daily enough food to yield the following numbers of Calories:

Absolute rest in bed without food	1680 Calories
Absolute rest in bed with food	1840 Calories
Office work or other light work, about	2500 Calories
Light muscular work	2700 Calories
Moderately active muscular work, as work of farmer or mechanic	3400 Calories
Hard muscular work	4000 Calories
Very hard muscular work	6000 Calories

The food requirements for boys are about as follows:

Under 2 years	900–1200 Calories
5–6 years	1300–1600 Calories
9–10 years	1700–2000 Calories
14–15 years	2600–3100 Calories
16–17 years	2700–3400 Calories

In a boys' school where most of the pupils were from 13½ to 16 years of age, the food used had a value of almost 5000 Calories for each pupil.

protein and the percentage of water in them is high; there is little resistance to infections; a feeling of lassitude and weakness is present; and, in the young, growth is not as rapid as it should be. In Europe during and since the war, great numbers of persons have been living on insufficient diets, and there is no doubt of the evil effects of undernourishment on the health.

Undernourishment Common. Investigations seem to indicate that about 30 per cent of children fail to eat enough to supply their energy needs, and in consequence are in a state of low vitality. These children are found in the families of both rich and poor, and the difficulty is that they either eat too little, or they are over-active, causing the body to consume the food too rapidly. Usually the trouble is that they eat only certain of the articles of food that are on the table. Appetite cannot be taken as a guide in eating, for many of those who habitually undereat are not troubled by hunger.

Symptoms of Undernourishment. Thinness is the surest symptom of lack of food, and a person who is thin should eat more or rest and sleep more.

Other symptoms of a lack of sufficient nourishment are languor, lack of mental alertness, lack of strength, and a general lack of vigor and energy. A child who is suffering from partial starvation often stands in the "fatigue position," the head and shoulders drooping forward and the scapulas standing out on the back. It seems probable that the incorrect posture of many children would correct itself if these children would eat enough food to make them vigorous and to cause them to lay on flesh. A person who wishes to increase his weight should take special care to eat a full meal three times a day.

Denmark's War Experiences with Food Regulation. In connection with a study of nutrition, the results of the food regulations in Denmark during the late war are of interest. The persons regulating the food supply of the country had previously satisfied themselves by careful experiment that whole-grain bread, if prop-

erly made, is a healthful food for man, and they believed that bran yields proteins very valuable for human nutrition. They also believed that if food is provided in sufficient amount, the supply of protein will take care of itself; and they believed that fat is not necessary if dairy products and green vegetables are used.

Accordingly, they refused to allow the feeding of potatoes or bran to meat animals, as was done in other countries, with the result that meat practically disappeared from the diet of the people. After living for a year on whole-grain bread, potatoes, vegetables (especially cabbage), milk, butter, and cheese, it was found that the death rate had been reduced 34 per cent, and it was estimated that the food blockade of Denmark in one year saved more than 6300 lives.[1] The per capita supply of food in Denmark was very small, and the Danes claim that they escaped the suffering that overtook the people of the central European countries only because they managed their food matters more scientifically.

Diets for Hot and Cold Weather. Proteins increase the oxidation of foods within the cells, experiments on a dog having shown that the heat production of the body can be increased 20 per cent by feeding protein. A diet rich in meat, therefore, enables one to resist the cold better in winter; but it is heating in summer, and a diet including liberal amounts of fruits and vegetables is better for hot weather.

The weight of the body may also be affected by the amount of protein in the diet. Since proteins accelerate the oxidizing process which consumes the food and tissues and thus lightens the body weight, persons who wish to reduce their weight are advised to eat protein rather than sugar, starches, and fats. Those who wish to increase their weight need to include in the diet liberal amounts of carbohydrates and fats, but, of course, sufficient protein for building purposes must be taken.

[1] The 1918–19 influenza epidemic made it impossible to compare vital statistics satisfactorily after the first year.

FOOD VALUES

Name of Food	Inedible Portion	Edible Portion					Per Cent of Available Protein Fat and Carbohydrate in Food as Purchased			Fuel Values of Food as Purchased	
		Water	Available nutrients								
			Protein	Fat	Carbo-hydrate		Protein	Fat	Carbo-hydrate	Per pound	Per 100 grams
	%	%	%	%	%		%	%	%	Cals.	Cals.
Apples . . .	25	84.6	.3	.5	12.8		.225	.375	9.6	198	43
Bananas . . .	35	75.3	1	.5	19.9		.65	.325	12.9	265	58
Beans (dried) .	—	12.6	15.8	1.6	59.9		15.8	1.6	59.9	1475	325
Beef (round) .	7.2	65.5	19.7	12.9	—		18.2	11.9	—	840	185
Bread (white) .	—	35.3	7.1	1.2	52.3		7.1	1.2	52.3	1155	254
Bread (graham)	—	35.7	6.9	1.6	51.3		6.9	1.6	51.3	1150	253
Breakfast food[1] .	—	9.6	9.3	1.6	74		9.3	1.6	74	1617	356
Butter	—	11	1	80.8	—		1	80.8	—	3427	755
Cabbage . . .	15	91.5	1.2	.3	5.5		1	.25	4.675	116	25
Candy	—	—	—	—	95		—	—	95	1767	389
Cheese . . .	—	34.2	25.1	32	2.4		25.1	32	2.4	1861	410
Corn meal . .	—	12.5	7.5	1.7	73.5		7.5	1.7	73.5	1578	347
Corn (canned) .	—	76.1	2.1	1.1	18.3		2.1	1.1	18.3	426	94
Eggs (boiled) .	11.2	73.2	12.8	11.4	—		11.3	10	—	632	139
Filberts . . .	52	3.7	13.3	58.8	11.7		6.3	28.2	5.6	1411	311
Fish[2]	54.8	76.7	20	1.6	—		9	.72	—	198	43
Fowl[3]	25.9	63.7	18.7	15.5	—		13.8	11.48	—	741	163
Milk (whole) .	—	87	3.2	3.8	5		3.2	3.8	5	312	68.9
Milk (skimmed)	—	90.5	3.3	.3	5.1		3.3	.3	5.1	169	37.2
Mutton (loin) .	16	50.2	15.5	31.4	—		13	26.3	—	1351	298
Oatmeal (dry) .	—	7.8	13.4	6.6	65.2		13.4	6.6	65.2	1740	383
Peanuts . . .	25	9.2	21.9	34.7	22		16.4	26	16.5	1710	376
Peas (green) .	45	74.6	5.2	.5	16.7		2.86	.275	9.18	235	51
Pork (fresh loin)	19.7	5.2	16.1	28.6	—		12.9	22.96	—	1208	266
Pork (salt ham)	13.6	40.3	15.8	36.9	—		13.6	31.88	—	1598	352
Potatoes (white)	20	78.3	1.7	.1	17.7		1.36	.08	14.16	292	64
Potatoes (sweet)	20	69	1.3	.6	26.2		1.04	.48	20.9	428	94
Prunes (dried) .	15	22.3	1.6	—	66.1		1.36	—	56.1	1070	235
Raisins (dried) .	10	14.6	2	3	68.7		1.8	2.7	61.8	1296	285
Rice	—	12.3	6.5	.3	76.9		6.5	.3	76.9	1564	344
Strawberries . .	5	90.4	.8	.5	6.8		.76	.475	6.46	154	33
Sugar	—	—	—	—	100		—	—	100	1860	410
Tomatoes . . .	—	94.3	.7	.4	3.8		.7	.4	3.8	100	22
Watermelos . .	60	92.4	.3	.2	6		.12	.08	2.4	50	11

[1] Wheat. [2] Black bass, whole. [3] Chicken, feathers removed.

DISTRIBUTION OF VITAMINS IN SOME COMMON FOODS

Name of Food	Fat Soluble Vitamin	Anti-beriberi Vitamin	Anti-Scorbutic Vitamin
Foods of Animal Origin			
Lean meat — beef, mutton, etc.	x	x	x
Liver	xx	xx	o
Canned meats	—	very slight	—
Sweetbreads	x	xx	—
Fish, white	o	very slight	—
Fish, fat — salmon, herring, etc.	xx	—	—
Eggs, fresh	xx	xxx	—
Eggs, dried	xx	xxx	—
Milk, whole raw	xx	x	x
Milk, condensed, sweetened	x	x	—
Butter, cod-liver oil, beef fat	xxx	o	—
Lard	o	—	—
Cheese, whole milk	x	—	—
Foods of Vegetable Origin			
Whole grain — wheat, rye, maize	x	x	o
White wheat flour	o	o	o
Polished rice	o	o	o
Olive, cottonseed, coconut oil	o	—	—
Cabbage, fresh raw	xx	x	xxx
Lettuce	xx	x	xx
Turnips (Swedes), raw juice	—	—	xxx
Carrots, fresh, raw	x	x	x
Potatoes, raw	x	x	less than x
Orange juice, fresh	—	—	xxx
Bananas	x	x	very slight
Tomatoes, canned	—	—	xx
Nuts	x	xx	—

xxx = very abundant, xx = moderately abundant, x = smaller amount.

ONE-HUNDRED CALORY FOOD PORTIONS, WITH CALORIES IN PROTEIN, CARBOHYDRATE, AND FAT[1]

Name of Food	"Portion" Containing 100 Calories Roughly Described	Weight of 100 Calories		Calories from		
		Grams	Oz.	Protein	Fat	Carbohydrate
Cooked Meats						
Beef, round, boiled (med. fat)	Small serving	44	1.6	60	40	00
Chicken as purchased, canned	One thin slice	27	.96	23	77	00
Lamb, leg, roast	Ordinary serving	50	1.8	40	60	00
Pork, ham, boiled	Ordinary serving	32.5	1.1	28	72	00
Veal, leg, boiled	Large serving	67.5	2.4	73	27	00
Uncooked Meats						
Clams, round, in shell, edible portion, average	Twelve to sixteen	210	7.4	56	8	36
Mackerel (Spanish), whole, edible portion, average	Ordinary serving	57	2.	50	50	00
Oysters, in shell, edible portion, average	One dozen	193	6.8	49	22	29
Trout, brook, whole, edible portion, average	Two small servings	100	3.6	80	20	00
Turkey, edible portion, average	Two small servings	33	1.2	29	71	00
Vegetables						
Beans, baked, canned	Small side dish	75	2.66	21	18	61
Beans, string, cooked	Five servings	480	16.66	15	48	37
Beets, edible portion, cooked	Three servings	245	8.7	2	23	75
Carrots, cooked	Two servings	164	5.81	10	34	56
Corn, sweet, cooked	One side dish	99	3.5	13	10	77
Peas, green, canned	Two servings	178	6.3	25	3	72
Potatoes, boiled	One large-sized	102	3.62	11	1	88
Potatoes, sweet, cooked	Half of average potato	49	1.7	6	9	85
Dairy Products						
Butter, as purchased	Ordinary pat or ball	12.5	.44	.5	99.5	00
Buttermilk, as purchased	1½ glass	275	9.7	34	12	54
Cheese, full cream, as purchased	1½ cubic inches	23	.82	25	73	2
Cream	¼ ordinary glass	49	1.7	5	86	9
Milk, whole, as purchased	Small glass	140	4.9	19	52	29

[1] Abridged from tables published in *The Journal of the American Medical Association*, 1907, xlviii, page 1320. These tables were compiled by Dr. Irving Fisher of Yale University.

ONE-HUNDRED CALORY FOOD PORTIONS, ETC. — *Continued*

Name of Food	"Portion" Containing 100 Calories Roughly Described	Weight of 100 Calories		Calories from		
		Grams	Oz.	Protein	Fat	Carbohydrate
Fruits (Dried)						
Dates, edible portion, average	Three large	28	.99	2	7	91
Figs, edible portion, average	One large	31	1.1	5	0	95
Prunes, edible portion, average	Three large	32	1.14	3	0	97
Raisins, as purchased	. . . . . .	31	1.1	3	9	88
Fruit (Fresh or Cooked)						
Apples, as purchased	Two apples	206	7.3	3	7	90
Apricots, cooked	Large serving	131	4.61	6	0	94
Bananas, yellow, edible portion, average	One large	100	3.5	5	5	90
Cantaloupes	Half ordinary serving	243	8.6	6	0	94
Grape juice	Small glass	120	4.2	0	0	100
Olives, ripe	About seven olives	37	1.31	2	91	7
Oranges, as purchased, average	One very large	270	9.4	6	3	91
Peaches, as purchased, average	Three ordinary	290	10.	7	2	91
Pears	One large pear	173	5.40	4	7	89
Strawberries, as purchased, average	Two servings	260	9.1	10	15	75
Cakes, Pastry, Pudding and Desserts						
Cake, chocolate layer, as purchased	Half ordinary square piece	28	.98	7	22	71
Cake, sponge, as purchased	Small piece	25	.89.	7	25	68
Custard, milk	Ordinary cup	122	4.29	26	56	18
Pie, apple, as purchased	One-third ordinary piece	38	1.3	5	32	63
Tapioca, cooked	Ordinary serving	108	3.85	1	1	98
Sweets and Pickles						
Honey, as purchased	Four teaspoonfuls	30	1.05	1	0	99
Olives, green, edible portion	Seven olives	32	1.1	1	84	15
Sugar, granulated	Three teaspoonfuls or 1½ lumps	24	.86	0	0	100
Sirup, maple	Four teaspoonfuls	35	1.2	0	0	100
Nuts						
Almonds, edible portion, average	About eight	15	.53	13	77	10

ONE-HUNDRED CALORY FOOD PORTIONS, ETC. — *Continued*

Name of Food	"Portion" Containing 100 Calories Roughly Described	Weight of 100 Calories: Grams	Weight of 100 Calories: Oz.	Calories from: Protein	Calories from: Fat	Calories from: Carbohydrate
Nuts — Continued						
Brazil nuts, edible portion . .	Three ordinary size	14	.49	10	86	4
Filberts, edible portion, average	Ten nuts . . .	14	.48	9	84	7
Peanuts, edible portion, average	Thirteen double	18	.62	20	63	17
Pecans, polished, edible portion	About eight . .	13	.46	6	87	7
Walnuts, California, edible portion	About six . .	14	.48	10	83	7
Cereals						
Bread, corn (johnnycake), as purchased, average	Small square .	38	1.3	12	16	72
Bread, white, home-made, as purchased	Ordinary thick slice . . .	38	1.3	13	6	81
Crackers, graham, as purchased .	Two crackers .	23	.82	9	20	71
Hominy, cooked	Large serving .	120	4.2	11	2	87
Macaroni, average, cooked . .	Ordinary serving	110	3.85	14	15	71
Oatmeal, average, boiled . . .	1½ serving . .	159	5.6	18	7	75
Rice, boiled, average	Ordinary cereal dish . . .	87	3.1	10	1	89
Spaghetti, average	. . . .	28	.97	12	1	87
Zwieback	Size of thick slice of bread . .	23	.81	9	21	70
Miscellaneous						
Eggs, hen's, boiled	One large egg .	58	2.1	32	68	00
Soup, bean, as purchased, average	Very large plate	150	5.4	20	20	60
Soup, cream of celery, as purchased, average	Two plates . .	180	6.3	16	47	37
Clam chowder, as purchased . .	Two plates . .	230	8.25	17	18	65

References. Locke's *Food Values* (D. Appleton & Co.) gives the chemical and energy values of average helpings of foods, which makes it easy to calculate the value of a given diet. Gephart and Lusk's *Analysis and Cost of Ready-to-Serve Foods* is very instructive and is of especial value to those who eat in restaurants. It may be purchased from the *Journal of the American Medical Association*, Chicago, for 15 cents.

MINERALS IN CERTAIN FOODS

Name of Food	Percentage of Certain Minerals in Ash of Edible Portion					Excess Acid-forming Elements per 100 Calories [1]	Excess Base-forming Elements per 100 Calories [1]
	Calcium (CaO)	Potassium (K_2O)	Phosphorus (P_2O_5)	Iron	Sulphur		
Apples	.014	.15	.03	.0003	.005		5.0
Beans (dried)	.22	1.40	1.14	.007	.22		2.9–6.8
Cabbage	.068	.45	.09	.0011	.07		10.0–13.6
Celery	.10	.37	.10	.0005	.025		40
Corn (whole)	.015	.17	.30	.0011	.116		0.4
Eggs	.093	.165	.37	.003	.19	9.0	
Milk	.168	.171	.215	.0002			3.3
Oatmeal	.13	.458	.872	.0036			3.2
Peas (dried)	.14	1.06	.91	.0056	.23		1.9
Potatoes (white)	.016	.53	.14	.0013	.03		9.0–12.0
Prunes (dried)	.06	1.20	.25	.0029	.03		7.9
Rice	.012	.084	.203	.0009	.105	2.4	
Steak (round) [2]	.011	.42	.50	.0038	.20	6.7	
Turnips	.089	.40	.117	.0005	.07		6.6–12.5
Wheat (whole)	.061	.519	.902	.0053	.17	2.6	
Wheat (flour)	.025	.146	.20	.0015	.17	2.7	

[1] Equivalent to cc. normal acid or normal alkali. [2] Lean.

References. Bulletin No. 28 of the United States Department of Agriculture, which may be purchased for 10 cents from the Superintendent of Public Documents at Washington, contains a very complete list of American foodstuffs, showing the protein, carbohydrate, fat, and energy values. Sherman's *Chemistry of Food and Nutrition* (Macmillan) contains a good treatment of the theory of nutrition and tables that are especially valuable in showing the mineral elements in foods.

QUESTIONS AND PROBLEMS

1 *gram protein* = 4.1 *Calories.*
1 *gram carbohydrate* = 4.1 *Calories.*
1 *gram fat* = 9.3 *Calories.*
1 *kilogram* = 2.2 *pounds.*
1 *pound* = 453.6 *grams.*
1 *ounce* = 28.3 *grams.*

To walk 1 *mile on the level requires for a man of average weight* (154 *pounds*) *energy equal to* 59 *Calories.*

To ascend 100 *feet* (*as in climbing a hill or a flight of steps*) *requires energy equal to* 15.4 *Calories.*

One hundred grams of dry protein per day is about an average allowance. Sixty grams is a very low protein diet. Fifty to 60 *grams of fat is a normal daily allowance.*

A man is too fleshy and wishes to reduce his weight. Suppose that he eats just enough to support his body without exercise. How far must he walk to take off five pounds of fat?

A six-year-old boy needs about half as much food as a man. What would be a fair amount of carbohydrate for a boy of this age? If a six-year-old boy bought half a pound of candy and ate it all in one day, in addition to his usual food, how much carbohydrate would he get that day?

Suppose that in walking you use the same energy in proportion to your weight as does the average man. How much energy will you use in walking a mile?

How much energy would you use in climbing to the top of the tallest building that you know?

How much energy would be required to bring you from your home to your place in the schoolroom?

How much potatoes would a man need to eat to get 100 grams of protein?

How much beef would he need to eat to get 3000 Calories of energy? How much protein would this give him?

In balancing diets, it is more convenient to use as a basis for computation the Calories derived from each of the different classes of foods than to find the amount of protein, fat, and carbohydrate in grams. For persons doing moderate work, about $\frac{1}{8}$ of the Calories should come from protein. From the table on pages 353–355 make up a diet that will yield approximately 3000 Calories of heat with 375 Calories from the protein, 500 from fat, and the remainder from carbohydrate.

As nearly as possible, estimate the total Calory content of your food for a day and the Calories derived from each class of food.

If a man eats 100 grams of protein and 100 grams of fat a day, how much carbohydrate will he need to give him 4000 Calories of heat?

Look up the analyses of white bread (or white flour) and meat in all the tables. Would a diet composed chiefly of these be low or high in minerals? in vitamins?

Would a diet of bread and milk be an improvement on a bread and meat diet?

A boy lost $1\frac{1}{2}$ pounds on a day when he attended a school picnic and all the children had lunch together. What was the probable cause of the loss in weight?

Would a person be more likely to gain in weight if he lay down for a rest each day? Why?

B. VENTILATION

Notwithstanding all the studies of ventilation that have been made, there yet seems to be something about the subject that is not understood, — "We are still undecided as to why bad air is bad." It has been found, however, that our heat-regulating mechanism is not so effective as has been supposed; that the temperature of the body may rise a degree or more in a heated room; and that one important point in ventilation is the control of the body heat. All the recent researches on the subject indicate that in crowded rooms the chief difficulty is overheating, and that in the solution of the problems of ventilation, the thermometer must play an important part.

The Humidity of the Air. When the bulb of a thermometer is wet, the mercury in the thermometer at once falls, because it is cooled by the evaporation of the water. The amount it falls depends on how rapidly the water evaporates, and this depends on the dryness of the air, dry air taking up the water more rapidly than moist air. By noting how much a thermometer is cooled when the bulb is wet, the humidity of the air can be learned, as you will understand by performing the following experiment:

Take the temperature of the air in your schoolroom with a thermometer, and let us suppose that you find it to be 70 degrees. Then wrap a piece of thin cloth about the bulb of the thermometer, moisten

the cloth with water that is near room temperature, and either fan the thermometer vigorously for two or three minutes or swing it through the air, taking care that the heat of the body does not affect it. Read the thermometer again. For convenience, we will suppose that the wet-bulb temperature is 59 degrees, which will give a difference between the dry-bulb and wet-bulb temperatures of 11 degrees.

Now turn to the table on page 360, and find 11 degrees in the row of figures across the top. Come down the column to the number opposite 70 degrees in the left-hand column, and you will have the relative humidity of the air, 52 per cent in this instance. In this way you can at any time find the humidity of the air if you know the wet-bulb and dry-bulb temperatures. You can also by the use of the table find the wet-bulb temperature of the air when the humidity and the dry-bulb temperature are given. For example, to find the wet-bulb temperature when the dry thermometer registers 90 degrees and the humidity is 81 per cent, you find 90 degrees in the column on the left of the table, move to the right to 81 per cent, and then look at the top of the column for the difference between the wet and dry thermometers, 5 degrees in this instance. Subtracting this from 90 degrees, we find that the wet-bulb temperature is 85 degrees. Find the wet-bulb temperature when the air is 110 degrees and the humidity is 32 per cent.

Importance of the Wet-bulb Temperature. The human body acts like a wet-bulb thermometer, and it is the wet-bulb and not the dry-bulb temperature of the air that is important. An understanding of this point will make plain to you at once why it is that the summers in humid regions are oppressive, even when the temperature of the air is not excessively high, and why in the "dry heat" of arid regions people retain their vigor and working power in an astonishing manner. It will also enable you to understand why the temperature of the moisture-laden atmosphere in crowded rooms must not be allowed to rise, and why in the atmosphere of a furnace-heated building, where the air humidity may be only 20 or 30 per cent, one may feel cold unless the temperature is raised to 75 degrees. The proper humidity for indoor air is from 40 to 50 per cent.

RELATIVE HUMIDITY TABLE

Temperature of Air	Difference between Wet and Dry Thermometers														
	1°	3°	5°	7°	9°	11°	13°	15°	17°	19°	21°	23°	25°	27°	29°
60°	94	84	73	63	53	44	34	26	18	10	2				
65°	95	85	75	65	56	48	39	31	24	17	10	3			
70°	95	86	77	68	60	52	44	36	29	23	16	10	4		
75°	95	87	78	70	62	55	47	40	34	27	21	16	10	5	
80°	96	87	79	72	64	57	51	44	38	32	26	20	15	10	6
85°	96	88	80	73	66	60	53	47	41	36	30	25	20	15	11
90°	96	88	81	75	68	62	56	50	44	39	34	29	24	20	15
95°	96	89	82	76	69	63	58	52	47	42	37	32	28	23	19
100°	97	90	83	77	71	65	59	54	49	44	39	35	31	27	23
105°	97	90	84	78	72	66	61	56	51	46	42	38	33	30	26
110°	97	90	84	78	73	67	62	57	53	48	44	40	36	32	28
115°	97	91	85	79	74	69	64	59	54	50	46	42	38	34	31
120°	97	91	85	80	75	70	65	60	56	51	47	44	40	36	33

Relative Humidity of Air in Percentages

Cooling the Body by Air Currents. Place a wet-bulb thermometer in still air and note the reading. Then fan it vigorously and take a second reading. What causes the mercury to fall? The importance of ventilating systems and fans in hot weather for cooling the body by sending air currents over it is only beginning to be understood, and they will be much more extensively used in the future. This will prove to be an economy, for by these devices the health of workers is preserved and their productive powers are greatly increased.

Clothing and Over-heating of the Body. Most of us understand the importance of heavy clothing in cold weather, but during the heated season many persons, especially men, do not wear clothing adapted to the weather. On hot days, thin clothing that will allow the air to penetrate to the skin and the perspiration to evaporate from the surface of the body should be worn. Bare arms, low-cut shoes, and clothing open at the neck, all allow the escape of body heat and help to keep the body temperature from rising. A light diet is also advisable in hot weather; for a heavy protein diet increases the oxidation of food and releases more heat in the body. These measures are important; for overheating of the body is very injurious, and we should give the same attention to keeping cool in summer that we give to keeping warm in winter.

C. ALCOHOL AND LENGTH OF LIFE

In 1909 forty-three of the leading life insurance companies of the United States and Canada decided to investigate collectively the death rates among different classes of their policyholders. The investigation included the histories of over 2,000,000 lives, and was the most extensive study ever undertaken by life insurance companies. Among other figures collected were the following in regard to the mortality rates among users of alcoholic drinks:

	MORTALITY
Moderate users (2 glasses of beer, one glass of whisky, or their equivalent, a day)	118 %
Liberal users (steady, free, but not immoderate use)	187 %

These figures indicate that 118 moderate users of alcoholic drinks and 187 liberal users of them die where the number of deaths that would naturally be expected is 100.[1] It should be understood, however, that

[1] Insurance companies from their long experience are able to calculate about how many deaths may be expected to occur among a given number of persons of given ages. This average number is taken as 100 %, and the rate among users of alcohol was compared with the average rate. It should be understood that the above comparisons are not between drinkers and abstainers, but between drinkers and all classes of the insured — drinkers and abstainers taken together. All companies reject applicants who are heavy drinkers.

the information as to the consumption of alcohol, was obtained when the policy was applied for, and a portion of those included in the above results probably changed their habits later. Some of them doubtless came to drink more freely and some became total abstainers.

In the above-mentioned investigation, no study of the mortality rate among abstainers was made, but one American company that made such a study secured the following data:

	Mortality
Total abstainers	59%
Rarely use	71%
Temperate	84%
Moderate	125%

These figures show a mortality rate among abstainers of less than half that among moderate drinkers.

D. INTESTINAL DISEASES

The long intestinal tract affords a favorable place for the growth of parasites, and the parasites find an easy mode of entrance to this tract in the food and water that are taken in through the mouth. Children, especially, suffer from intestinal diseases, and because these diseases cause so much sickness and so many deaths, it is important that their cause and the means of prevention be understood.

Diarrhea. Diarrhea may be caused by several different bacteria, all of which grow in the intestine, and most of which are closely related to the typhoid germ. One of these germs causes the very severe form of diarrhea that runs in epidemics, and is sometimes called *flux*. Poisoning from meats, fish, old milk, and ice cream is often due to germs related to the diarrhea bacteria. The germs grow in the food either before or after it is eaten, and produce the toxins that cause the poisoning.

Infant Diarrhea. Summer complaint, from which so many young children die, is caused usually by germs belonging to this same group. The disease may easily be started in a little baby by giving it impure water, and nothing but boiled water, pure rain water, or artesian water should ever be given to a little child or put into its milk.

Nearly all milk contains germs that, when taken in large enough numbers, will cause the trouble, and the milk supply is mainly responsible for the disease. The disease is worse in summer because in warm weather the germs multiply more rapidly in milk, and also because the heat weakens the children so that they have not much power of killing germs. The disease is infectious, and in some cities great progress in preventing it has followed isolating the cases and disinfecting the wastes, as is done in cases of typhoid fever.

How the Germs of Intestinal Diseases are Spread. The germs of diarrhea, dysentery (page 296), and typhoid fever are usually swallowed either in food or water. They are carried about and get into the food and water in various ways (page 315), but one especially important precaution in the prevention of all these diseases is to keep discharges from the intestines away from flies.

Hookworms. The hookworm is a slender white worm, not quite half an inch in length. It grows in the intestines, and causes a profound anemia (lack of red blood corpuscles). Hookworms are found in the warmer parts of all the continents; they formerly caused one third of all the deaths in Porto Rico, and it is estimated that in our own country south of the Potomac River from 20 to 25 per cent of the poorer white people suffer from hookworms.

How Hookworms get into the Body. The eggs of the hookworm pass out of the body in the excreta from the alimentary canal. If they are allowed to get into the soil, they develop into worms so small that there may be fifty of them in a piece of earth the size of a pea. These worms may enter the body through the skin (in which they cause "ground itch"), be carried in the blood to the lungs, break through into the air sacs and crawl up the trachea, and then reach the intestines by being swallowed; or they may be taken into the alimentary canal in water or in food. The disease is more common among children than among adults, because children go barefooted, and sometimes eat with unwashed hands after playing in the earth; it is more common among agricultural laborers and brickmakers than among those who do not come in contact with the soil; and the dis-

ease is more severe (though not more common) in the white than in the colored race.

The Prevention of Hookworm Disease. The eggs of the hookworm get into the soil only from persons who have the disease. Away from the air the eggs die, and the disease may be entirely prevented by the use of closets. In hookworm regions great care, therefore, should be exercised to prevent the pollution of the soil about houses. To a certain extent, children may be saved from infection by the wearing of shoes, but keeping the soil free from pollution is the important measure in the prevention of hookworm disease.[1]

Preventing Disease in Rural Regions. Intestinal diseases like typhoid fever, dysentery, and hookworm are especially prevalent in rural regions, and every county needs a health officer who will give his time to showing the country people how to free themselves from these diseases. The one thing above all others that is needed to check them is a sanitary closet on every farm in the land. Such a closet must be fly-tight; for as long as flies are allowed to spread the germs of intestinal diseases over foods and dishes, not even a beginning in sanitation has been made.

In this connection it is of interest to note that from 1900 to 1912 in the United States the death rate in cities fell 21.2 per cent, and that during the same years in the rural regions it fell only 8.6 per cent. The reasons for this are that in cities the schools have physicians and nurses to look after any children that need medical care; cases of diphtheria, measles, and typhoid fever are quarantined; and skilled health officers devote their whole time to guarding the people's health. In the country there is no one to do this work, and the country people are not getting the benefit of recent scientific and medical discoveries.

[1] Often it is not realized that hookworm victims are diseased, and they are considered lazy and ambitionless. Many cases of hookworm trouble are mistaken for malaria. The symptoms of hookworm disease are paleness, thinness, dull skin and eyes, dry hair, continued weakness, and sometimes an appetite for such substances as earth, tobacco ashes, and paper. The worms may readily be killed and the disease cured by the use of very simple medicines.

GLOSSARY

This glossary is intended chiefly to help the pupil in the pronunciation of the more difficult terms. Words are defined only where no exact definition is found in the text. The numbers refer to the pages on which definitions are found.

afferent (af′fe-rent), *carrying to.*
ameba (am-ē′ba), 296.
amylopsin (ă-mĭ-lŏp′sin), 98.
Anopheles (an-ŏf′ĕl-ēz), 321.
aorta (ā-or′ta), 141.
aqueous (ā′kwē-us), *watery.*
arachnoid (a-răk′noid), *like a cobweb; as, arachnoid membrane.*
arbor vitæ (ar′bor vī′tē), 215.
arytenoid (ă-rĭ-tē′noid), 173.
bacillus (bă-sĭl′lus), 304.
bacteria (bak-tē′re-a), 285.
biceps (bī′seps), 67.
bronchial (bron′ke-al), 166.
canine (kā-nīn′), 95.
capillary (căp′il-la-re), 141.
carbohydrate (kar-bō-hī′drāt), 82.
cartilage (kar′til-āj), *gristle.*
cerebellum (sĕr-e-bĕl′lŭm), 25.
cerebro-spinal (sĕr′e-brō-spī′nal), 26.
cerebrum (sĕr′e-brŭm), 25.
choroid (kō′roid), 261.
cilia (sĭl′e-a), plural of **cilium**; *minute, hair-like projections.*
coccus (kŏk′ŭs), 304.
coccyx (kŏk′six), 34.
cochlea (kŏk′lē-a), 254.
corpuscle (kor′pusl), *a cell of the blood or lymph* (page 147), *or a group of cells, as a renal corpuscle* (page 188).
cricoid (krī′koid), 172.
Culex (kyu′lex), 321.
cytoplasm (sī′tō-plazm), 4, footnote.
dentine (dĕn′tĭn), 94.
diaphragm (dī′a-fram), 17.
dietetics (dī-ĕ-tĕt′iks), *the science or study of the regulation of the diet.*
diphtheria (dif-thē′re-a), 304.
dura mater (du′ra mā′ter), 26.
efferent (ef′fe-rent), *carrying from.*
enzyme (ĕn′zĭm), 112.
epiglottis (ep-ĭ-glŏt′tis), 165.
esophagus (e-sŏf′a-gus), 90.
Eustachian (yu-stāk′e-an), 253.
fasciculus (fas-sĭk′yu-lus), *a bundle.*
femur (fē′mer), 37.
fibula (fib′yu-la), 37.
formaldehyde (for-măl′de-hīd), 335.
fungus (fun′gŭs), plural **fungi** (fun′-jī), 318.
hemoglobin (hem-ō-glō′bin), 148.
hepatic (hē-păt′ik), *pertaining to the liver;* as, *hepatic vein.*
hydrogen (hī′drō-jĕn), 80.
incisor (in-sī′sor), 95.
infundibulum (in-fun-dĭb′yu-lum), 166.

invertase (in-ver′tās), 113, footnote.
lachrymal (lăk′ri-mal), *pertaining to the tears;* as, *lachrymal duct.*
lacteal (lăk′te-al), 152.
larynx (lăr′inks), 165.
lymph (lĭmf), 149.
lymphatic (lim-făt′ik).
malleus (mal′le-us), 253.
medulla oblongata (med-ŭl′la ob-lŏn-gah′ta), 25.
Meibomian (mī-bō′mi-an), 260.
membrane (mem′brān), *a thin layer of tissue.*
meningitis (men-in-jī′tis), 308.
molecule (mŏl′e-kyul), 79.
mucus (myu′kus), 168.
neuron (new′ron), 211.
nitrogen (nī′trō-jĕn), 80.
nucleus (new′kle-us), 4.
olfactory (ol-făk′to-re), *pertaining to the sense of smell.*
pancreas (pan′kre-as), 98.
papilla (pa-pĭl′la), 193.
parotid (pa-rōt′id), 97.
patella (pa-tel′la), 37.
peptone (pĕp′tōn), 112.
perimysium (per-e-mĭz′e-um), 62.
periosteum (per-e-ŏs′te-um), 42.
phalanges (fa-lăn′jēz), 37.
pharynx (făr′inks), 90.
pia mater (pī′a mā′ter), 26.
process (prŏ′sess), *a slender, projecting point.*
proteins (prō′te-ins), 83.
protoplasm (prō′tō-plazm), *the living substance of the cell.*
protozoön (prō-tō-zō′ŏn), plural **protozoa** (prō-tō-zō′a), 285.
psoas (sō′as), 70.
ptyalin (tī′a-lin), 98.
pulmonary (pŭl′mo-na-re), *having to do with the lungs.*
pylorus (pī-lō′rus), 93.
rabies (rā′be-ēz), 299.
renal (rē′nal), *pertaining to the kidneys;* as, *renal corpuscle.*
retina (rĕt′i-na), 261.
sacrum (sā′krum), 34.
salivary (săl′i-va-re), 89.
scapula (skăp′yu-la), 36.
sclerotic (skle-rŏt′ik), 261.
sebaceous (se-bā′shus), 195.
spirillum (spī-ril′lum), 304.
stapes (stā′pēz), 253.
steapsin (stē-ăp′sin), 98.
subcutaneous (sub-kyu-tā′ne-us), 193.
submaxillary (sub-măks′il-la-re), 97.
tetanus (tĕt′a-nus), 313.
thoracic (thō-răs′ik), *connected with the chest,* from **thorax**, *chest.*
thyroid (thī′roid), 172.
trachea (trā′ke-a), *the windpipe.*
trapezius (trap-ē′ze-us), 60.
triceps (trī′seps), 67.
trichina (trĭ-kī′na), 129.
trichinosis (trĭk-ĭ-nō′sis), 129.
trypsin (trĭp′sin), 98.
tuberculosis (tu-ber-kyu-lō′sis), 340.
tympanic (tĭm-păn′ik), 252.
tympanum (tĭm′pan-um), 253.
urea (yu′rē-a), 116.
ureter (yu-rē′ter), 188.
uvula (yu′vyu-la), 165.
vena cava (vē′na kā′va), plural **venæ cavæ** (vē′nē kā′vē), 142.
vitreous (vĭt′re-us), *like glass.*

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A star (*) after a page number indicates that an illustration of the subject appears on that page.